

Instrumentation and Monitoring Bootcamp: Planning, Execution, and Measurement Uncertainty for Structural and Geotechnical Construction Projects

Purpose and Background

The use of field instrumentation to monitor the on-site behavior of structures is becoming part of many construction projects. Nevertheless, few universities offer a course on instrumentation as part of their civil engineering curriculum; therefore, many engineers learn instrumentation through the school of hard knocks. This continuing education seminar will fill a void in the education of most civil engineers.

This seminar will provide a comprehensive introduction to instrumentation and monitoring of civil engineering projects including planning, design of instrumentation programs, performance of commonly used sensors, data acquisition, signal conditioning, error analysis, information management, and case histories. It will combine elements from civil, mechanical, and electrical engineering together with some management concepts in a coherent modular format. A key goal in the course development is to produce material that is suitable for typical civil engineers who are not well versed in electrical and mechanical systems without watering down the content.

The population of the world is likely to increase by 25 percent in the next 50 years. Virtually all of this growth will be in cities in need of major infrastructure renewal. Rehabilitation work is different from conventional construction in a number of ways. First, the work is complex and inter-disciplinary in nature. Second, the impact on adjacent buildings and utilities is great. Third, the subsurface site conditions can never be fully predicted in advance. Fourth, soil properties can vary dramatically within one site, and even within the same soil formation, depending on the site history. Fifth, environmental risks on developed land are different and greater than virgin soils. The demands and uncertainties involved in modern infrastructure renewal projects point to the need to use instrumentation on many current projects.

Seminar Instructor

MAGUED ISKANDER, PH.D., P.E., F.ASCE, is Professor and Head of the Civil and Urban Engineering at New York University (formerly Polytechnic University and Polytechnic Institute of NYU). He has over twenty-five years of experience in analysis, design, and construction of foundations including teaching, research, and consulting. He is experienced in rehabilitation, instrumentation, and field monitoring of distressed structures, retaining walls, and foundations. Dr. Iskander has authored three books, edited 9 books, and published over 120 papers dealing with measurements and instrumentation, experimental modeling, foundations, pedagogy, and urban geotechnology.

Professor Iskander served as Principal Investigator (PI) and Co-PI on over \$9 Million of research and educational grants and contracts. He is recognized as the leader of two areas of geotechnical research: (1) modeling of soil structure interaction and flow using transparent soil surrogates, and (2) behavior of piling made of recycled polymers. Additionally performed notable research on plugging of pipe piles, non-destructive testing of drilled shafts, seismic earth pressure, and soil structure interaction of rigidly framed structures. Notably he is a recipient of a National Science Foundation (NSF) career award dealing with development of a new method for measuring soil structure interaction and a Defense Threat Reduction Agency (DTRA) contract to visualize the fundamental physics of rapid earth penetration. He also received a Federal Highway Administration (FHWA) contract to assess the performance of non destructive testing (NDT) methods in foundations. Additionally, he is also Co-recipient of several NSF educational grants to modernize the teaching of science in New York City high schools by implementing sensors and data acquisition in laboratory curricula.

Professor Iskander is the recipient of a number of teaching awards, including Chi Epsilon James Robbins District Excellence in Teaching Award (2000), Polytechnic University Distinguished Teacher Award (2002) and Jacobs Excellence in Education Award (2006, 2009). Dr. Iskander holds a B.Sc. degree in Civil Engineering from Alexandria University and a Ph.D. degree in Geotechnical Engineering from the University of Texas at Austin. He is a registered professional engineer in New York, New Jersey, and Wisconsin.

- To register your group, contact **John Wyrick** (JWyrick@asce.org) or **Stephanie Tomlinson** (STomlinson@asce.org)

Summary Outline

DAY 1: Sensors

Strain Measurements

- Field and laboratory applications
- Vibrating wire (vw) strain gages - Theory of operation - Reading methods - Types and installation methods of vw gages
- Electrical resistance strain gages - Theory of operation - Strain gage factor - Wheatstone bridges - Selection & installation process - Optimizing excitation level

Measurement of Load

- Electrical resistance load cells
- Vibrating wire load cell
- Common load cell applications and case histories - Tiebacks and anchors - Diaphragm and sheet pile walls - Dams - Uplift forces - Load tests on piles, drilled shafts, and spread footings
- Selection and installation

Pressure Measurements

- Review of terminology the the Bernoulli equation
- Piezometers - Applications (geotechnical, environmental, hydraulic) - Observation wells - Vibrating wire piezometers - Pneumatic piezometers - Electrical resistance piezometers - Installation - Time lag
- Earth pressure cells - Operating principal - Installation on structures and in soils

Linear Deformation

- Linear potentiometers
- LVDT and DCDT
- Borehole extensometers
- Slope extensometers
- Soil strainmeters
- Settlement cells
- Joint meters

Measurement of Tilt

- Tiltmeters - Electrolytic (EL) tiltmeters - Force-balanced servo accelerometers - Vibrating wire tiltmeters
- Applications and case histories - Bridge monitoring - Rail track monitoring
- Inclinometers - Principal of operation - Tradition type (traveling) - In place type
- Optical measurements - Robotic total stations - Case histories

Dynamic Measurements Basics

- Accelerometers and Geophones
- Application
 - Pile driving
 - Blast monitoring

DAY 2: Information Management

Data Acquisition and Signal Conditioning

- Signals and sampling
- Analog and digital signals - Signal aliasing - Sample and hold circuit
- Signal conditioning - Amplifiers - Filters - Isolators - Modulators and demodulators
- Analog to digital hardware - Successive Iteration AD Converters - Delta sigma converters - Multiplexing - Data loggers - SCADA for civil engineering
- Power management
- Data management

Error Analysis

- Statistical basics
- Key terms in measurement uncertainty (conformance, accuracy, precision, resolution, sensitivity, range, linearity, hysteresis, noise, drift, and stability)
- Bias errors (systematic) - Maximum error - Probable error
- Precision errors (random) - Treatment of uncertainties - Confidence
- Curve fitting

Planning of Instrumentation Programs

- The observation method
- Systematic approach to planning a monitoring program
- Execution and case histories - Monitoring a bridge in Hong Kong - Instrumentation of a Chicago tunnel - Monitoring a parking garage in NYC
- Typical instrumentation layouts
- Business aspects

Seminar Benefits

- Find out what resources are available to help you ensure that your project is performing as planned
- Become familiar with the design, manufacture, selection, and installation process of both laboratory and field instrumentation
- Learn how to use the observational method to fine tune the design
- Learn how to design instrumentation programs that do not interfere with construction activities
- Avoid costly law suits by documenting actual project performance and setting thresholds for action
- Find out the latest trends in instrumentation

Assessment of Learning Outcomes

Achievement of the learning objectives will be assessed through a series of in class problem-solving exercises, design exercises, class discussion, and short case studies.

Learning Outcomes

Upon completion of this seminar, you will be able to:

- Identify all the applications for instrumentation and monitoring of civil infrastructure
- Explain how different sensors commonly used in civil engineering operate
- Use data acquisition and information management systems
- Identify and analyze common measurement errors
- Plan and design instrumentation and monitoring programs
- Summarize how to use instrumentation to achieve better project performance

Who Should Attend?

The seminar will benefit all individuals involved with the construction industry, including:

- Civil engineers
- Specialists in structural, geotechnical, and construction engineering
- Architects, builders, and developers
- Owner representatives and regulators
- Academics and graduate students planning experiments

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