International Working Group on SHM

SHM Glossary of Terms

◊ SHORT AND MEDIUM SPAN BRIDGES

◊ CABLE STAYED BRIDGES

◊ SUSPENSION BRIDGES

◊ BUILDINGS

◊ DAMS

◊ MARINE PLATFORMS

◊ HERITAGE STATUES

◊ OTHERS

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The SHM Glossary of Terms is a communication initiative of the recently formed International Working Group on Structural Health Monitoring (IWG on SHM). The purpose of this document is to begin the process of identifying and defining standard terms used in the emerging field of Structural Health Monitoring (SHM) of civil engineering structures. This document is one component of a larger compilation of information on SHM research and applications around the world.

The IWG on SHM is an international consortium of leading experts in the field of SHM who are dedicated to promoting the inherent value of Life Cycle Performance Management for Civil Infrastructure (LCMPI-CI), and the integral role that SHM plays in achieving sustainable infrastructure systems.

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Definitions

Accelerometer – a device used to measure accelerations induced by forced excitation, impact and ambient vibrations.
Commentary: Predetermining the vibration characteristics of a structure is the most critical for selecting an accelerometer. For bridges, low frequency and low amplitude accelerometers are suitable.

The most common types of accelerometers are:
- Piezoresistive accelerometers - suitable for measuring long duration pulses found in transportation vibration, automotive crash studies and blast testing.
- Capacitive accelerometers - suitable for low frequency, low level acceleration measurements, seismic measurements, and structural analysis and tilt measurements.
- Force balance accelerometers - very suitable for DC and low frequency responses providing milli-g measurement capacity.

Acoustic Emission Monitoring System (**Acoustic Attenuation**) – a system used to detect cracks in steel cables or members by measuring the acoustic emission released by crack propogation.
Commentary: These systems typically use an array of continuously operating high frequency sensors that detect the energy that is released when a wire fails. The sensor array also identifies the location of the crack or failure through triangulation of the measurements. Acoustic emission monitoring systems typically require sophisticated real-time processing and algorithms to detect the occurrence of cracks.

Adhesive Anchor -an anchor inserted into a hole drilled in hardened concrete and held in place by epoxy resin or other adhesive.

Ambient Vibration Test – a test to determine the free vibration characteristics of a structure that has been excited by wind, human activity, or traffic.
Commentary: Strategically placed accelerometers measure the response of the structure. The output from the accelerometer records accelerations against time. Selecting the locations and the number of accelerometers not only requires expertise in dynamic testing, but also requires detailed knowledge about the behaviour of the structure.

Analytical Technologies – analytical calculations used for bridge health monitoring.
Commentary: There are four main categories of analytical technologies.
- computer aided drafting (CAD) and reverse-CAD
- analytical modeling based on a macroscopic, element-level, microscopic finite element (FE) or a mixed approach
- linear analysis under static, moving or dynamic loads

- nonlinear analysis (push-to-collapse analyses) incorporating material non-linearity or geometric non-linearity, or both, or for cable-supported bridges, geometric nonlinear analysis

Anchor - a bolt, stud, or reinforcing bar embedded in concrete.

Assessment - estimating resistance and deformation values for a site by referring to values established for other sites with similar stratigraphy.
Commentary: An assessment is a set of activities that verifies the reliability of an existing structure for future use.

Average Annual Daily Traffic – in number of vehicles, total volume of traffic during a year divided by the number of days in the year.

Average Daily Traffic – in number of vehicles, total volume of traffic during a given time period, in whole days, greater than one day and less than one year, divided by the number of days in that time period.

Average Daily Truck Traffic – in number of vehicles, total volume of truck traffic during a given time period, in whole days, greater than one day and less than one year, divided by the number of days in that time period.

Behaviour Test – a static test used to study the mechanics of bridge behaviour, or to verify certain methods of analysis that will help develop confidence in the design of the structure.
Commentary: During behaviour testing, applied loading is usually kept at or below the level of maximum service loads.

Bond Length – the portion of a ground anchor that transmits the tendon force to the surrounding soil or rock.

Bonded Foil Resistance Strain Gauge – an electric resistance strain gauge that consists of a thin metallic film deposited on a non conducting plastic film.
Commentary: Bonded foil strain gauges are most suitable for short duration tests or intermittent monitoring of strains that vary rapidly in time. The operating principle for this type of gauge is based on the direct relationship between a change in the length of a conductor and the resulting change in the resistance of the conductor. These gauges are available in a number of patterns and configurations for surface and internal strain measurements including linear gauges, pair gauges and rosette gauges.

Bragg Grating Sensor – a fibre optic sensor used for measuring strains.
Commentary: The Bragg grating sensor uses an interference pattern that is etched directly onto the fibre by ultraviolet lasers. The sensor reflects a certain wavelength of light back through the fibre, depending on the spacing of the grating pattern. A change in the length of the fibre affects the wavelength that is reflected. This change in wavelength can then be correlated with strain.

Bridge - a structure that provides a roadway or walkway for the passage of vehicles, pedestrians, or cyclists across an obstruction, gap, or facility and that is greater than 3.0 metres in span.

Buckling Load - the load at which a member or element in compression reaches a condition of instability.

Buildability - property of a structure that enables construction to proceed in a safe, timely and economic fashion.

Cable Parameters for Data/Signal Transmission – used to describe and determine the performance of copper cables.
Commentary: These parameters include materials used for the conductor and insulation, wire gauge (conductor size), resistance, velocity of propagation, capacitance, inductance, and impedance. Other factors to consider include incorrect cable impedance, migration of the signal to the conductor skin, and national electric code requirements. These conditions are important in high frequency applications.

Cable-Stayed Bridge – a bridge with one or two towers and a suspended deck structure. The deck is pulled toward the towers in compression, and must be stiff in all stages of construction and use.

Cabling System for Data/Signal Transmission – a system of cables distributed over a structural health monitoring network.
Commentary: Cables are a necessary component of any health monitoring system that uses electronic sensors such as transducers. This is particularly true when the sensors are distributed over a network. The cabling system provides a flexible, accurate, and rugged platform that will facilitate reliable communication between various components.

There are two basic options available for system cabling, copper cables and fibre optic cables: a) copper cables can be used at almost any level of the system, from the connection of sensors to the structured backbone for networking, b) fibre optic cables are most often used for networking applications.

Characterization in Health Monitoring – a system of processing used in designing health monitoring applications.
Commentary: The characterization of health monitoring is usually established with respect to, or according to, the objective of measurment/monitoring. This process depends on the type of structure and the corresponding response, and the type of environmental exposure (wind, traffic load, seismic, temperature, corrosion, and humidity, etc).

Characterization of the monitoring application involves establishing the type, level, and duration of monitoring that is required to meet identified objectives. These characteristics will depend on the particular application scenario and, in turn, will

have a major influence on the type of equipment used and the strategy for managing the information that is generated.

Civionics – a new term coined from **Civi**l-Electr**onics** that relates to the application of electronics for the SHM of civil structures.

Concrete Dam – part of a joint at both sides of the joint opening, forming a solid and substantial damping device, providing protection against the dynamic impact of traffic wheels on the joint.

Continuous Monitoring – monitoring structures on a continual basis to investigate any detrimental change that might occur.
Commentary: Continuous monitoring is usually applied when
- The structure is extremely important,
- the structural integrity is in doubt,
- the structure is likely to be exposed to extreme events such as severe earthquakes and hurricanes, or
- the design includes an innovative concept with no performance history to indicate long-term worthiness.

Correlation Analysis – statistical technique that can determine whether pairs of variables are related.
Commentary: Correlation analysis studies help identify possible relationships between different pairs of variables. In a real application environment, correlation analysis might be divided into different levels.

Corrosion – Chemical phenomena occuring on the surface of the corroding metal; when the surface acts as a mixed electrode, coupled anodic and cathodic corrosion reactions take place.

Crash Test – type of test used on a barrier or highway accessory support.
Commentary: In crash tests, a vehicle is crashed into the barrier or highway accessory support at a specified speed and angle of impact, and the interaction of the crashing vehicle and the test subject matter is monitored.

Damage – unfavorable change in the condition of a strucutre that can affect structural performance.

Damping - the dissipation of energy in a structure oscillating in one of its natural modes of vibration.
Commentary: It is normally expressed as a ratio of the actual value of damping to the critical value of damping. The critical value of damping is the lowest value at which an initial motion decays without oscillation.

Data Acquisition (DAQ) Board – a device that converts analog signals from sensors into digital signals.

Commentary: DAQ boards that are installed inside a computer and use the computer's power supply are called plug-in boards. DAQ boards that have their own power supply are called stand-alone units. Certain archived are digital so therefore no conversion is required.

Data Acquisition (DAQ) Hardware – hardware device that generally consists of a number of electronic components that collects, conditions, converts and transmits sensor signals to a computer.
Commentary: - In most cases, the components of the DAQ hardware include a signal conditioner, an analog-to-digital converter, controlling circuitry, memory, a communications interface or device, a power supply, and a central processing unit (CPU).

Data Acquisition (DAQ) Peripherals –items used to connect sensors to data acquisition hardware and protect hardware components from exposure to the elements are considered sub-level of hardware. Connections include cables, terminal blocks and connectors, enclosures and junction boxes.

Data Acquisition (DAQ) Software – computer programs that control data aquisition and permit users to communicate with and manipulate DAQ systems that are connected to a computer.
Commentary: There are two forms of software used in conjunction with DAQ systems: driver software and application software.
- Driver software facilitates communication between the DAQ hardware, the computer operating system software, and the application software.
- Application software provides the link between the user and the DAQ system, permitting the user to configure and control the DAQ hardware, and to read, display, store and analyze measurements.

Data Acquisition (DAQ) System – type of system including hardware, software, and hardware peripherals, used to collect the signals generated by sensors, then condition and convert the signals into a suitable form, and finally transmit the signals to a computer.
Commentary: In general, a monitoring system captures low-frequency/long-term effects, high-frequency/short-term effects, environmental effects, and streaming or still images of incidents. Most DAQ systems share three primary components:
- hardware
- peripherals
- software

Data Acquistion (DAQ) Archiving and Processing Program – software that tells the computer how often and when to scan the DAQ board, how to process the collected data, and determines what data should be saved.
Commentary: Some suppliers provide programs with their DAQ boards. Others provide driver software with the board. Most suppliers offer their own DAQ

software, enabling the development of DAQ programs in an easy and usually graphical way.

Data Archival – storing large quantities of data accumulated during long-term monitoring of structures.
Commentary: Without proper planning and design, managing data can easily become a major issue. The data flow process begins with data collection and ends with data storage and integration. Data retrieval follows the storage and integration process only as a means to aid with data mining and analysis efforts.

Proper storage and analysis application development requires a clear choice of database management systems for design considerations. The selection of a database management system can be based on a shared file-based database or client/server databases. Shared file databases often are stored and accessed on local computers making access by remote users difficult. Client/server database management systems share information by having a centralized server-side processing capability.

Data Collection, Synchronization, and Storage – important functional system for collecting and organizing data for acquisition systems.
Commentary: The data collection process involves three main steps:
- data buffering
- data processing
- data storage

Data Filter – a filtration system that allows the extraction of specific components of a measured signal by removing 'noise' or 'dynamic responses'.
Commentary: In data filtration systems, signals contain phenomena other than the one of interest. Filters are used to extract this other type of information.

In reality, measurement signals have content across the entire frequency spectrum. By defining where the desired signal or noise falls, an appropriate filter that will extract only the desired signal can be built. For instance, electronic equipment often has noise induced by power (60 Hz noise). Applying a band reject filter at 60 Hz can easily eliminate this noise.

Data Mining - concept of transferring data into useful information.
Commentary: Data mining is useful in extracting refined information from large-scale databases. There are two basic concepts involved: data warehousing and data mining. Data warehousing is a large-scale database used to perform data mining, the process of searching, pattern matching, analyzing and strategic decision-making. The data mining system for a multidimensional database should initially include an OLAP (On-Line Analytical Processing) service.

Data Post-Processing and Quality Assurance of Stored Data – process for storing, packaging and tagging the data, and then transferring the data into proper storage and archival components.

Commentary: Generated data is often obtained through various monitoring regimes such as: field tests, and continuous or triggered measurements.

Dead Load - the load from material that is supported by the structure and is not subject to movement.

Deck - a component of a bridge superstructure that carries and distrtibutes wheel loads.

Deck Joint - a structural discontinuity between two components that permits relative rotation or translation between the two, where at least one is a deck component

Deck Slab - a solid concrete slab carrying and distributing loads to supporting beams.

Deck Width - the horizontal distance measured at deck level perpendicular to the direction travel, form face to face of sidewalks, curbs, or barrier walls if there are no curbs.

Design Lane - a longitudinal strip that is a fraction of the deck width, within which a truck or lane load is placed for the purpose of design or evaluation.

Design Life - a period of time specified by the Owner during which the structure is intended to remain in service.

Design Speed - the speed for which the highway at a bridge site is designed.

Diagnostic Test – type of static test conducted to establish the source of the distress or enhance the load-carrying capacity of a component, since the behaviour of a bridge component is usually affected by its interaction with other components.

Direct Strain Measurement – method for measuring the amount of deformation that a body undergoes when subject to an applied force.
Commentary: Strain is the ratio of the change in length of an element compared to the original undeformed length of the element; therefore strain is a dimensionless quantity. For bridge testing and monitoring applications, electrical resistance strain gauges and vibrating wire strain gauges are the most common gauges used to determine direct strain measurements on a structure. Apparent strains induced by free change in length that are caused by temperature changes should not be confused with load-induced strains. Temperature compensation should be used to eliminate induced apparent strain.

Divergence - an aerodynamic instability in torsion which usually occurs at wind speeds beyond the range normally considered in design.

Drag - a load in the direction of the wind, induced by an airstream acting on a body.

Dynamic Load Allowance - an equivalent static load, expressed as a fraction of the traffic load, corresponding to the dynamic increment of responses that are due to the interaction between the dynamic systems of the vehicle and the structure. *Commentary:* This load is considered equivalent to the dynamic and vibratory effects of the interaction of the moving vehicle and the bridge, including the vehicle response to irregularity in the riding surface.

Dynamic Load Allowance Test (DLA test) – type of test used to obtain information about representative values of the DLA which could be used in the formulation of Code provisions.

Dynamic Load Test – type of test that uses moving loads to excite the dynamic response of a bridge.

Dynamic Test - determination of the resistance, impact force, and developed driving energy of a driven pile, using analysis of measured strain induced by the driving of the pile.

Dynamic Analysis – type of analysis usually conducted to calculate the impact force, driving resistance, and energy of a pile by wave propagation theory, without using field measurements.

Edge Distance –the minimum distance between the anchor centreline and the free edge of the concrete.

Effective Depth - distance from the extreme compression fibre to the centroid of the tensile force.

Effective Prestress - stress or force remaining in the tendons or the concrete after all losses have occurred.

Effective Temperature - temperature that governs the thermally induced expansion and contraction of a superstructure.

Embedment Depth - distance from the bearing surface of the anchor in tension to the surface of the concrete.

Embedment Length - length of embedded reinforcement provided beyond a critical section.

Environmental Compatibility – environmental impact on a new bridge involving wind effects, air noise, and ground vibration, which may need to be evaluated.

Environmental Sensor – a type of sensor used to measure environmental conditions.

Commentary: In many applications it is desirable to measure environmental conditions at a test site. These measurements often include ambient temperature, relative humidity, and wind speed and direction.

A resistance temperature detector (RTD) is typically used to measure the ambient temperature. Relative humidity is typically measured using a thin film principle. The dielectric properties of the film change with changes in its water content. This produces a change in the capacitance of the sensor that is directly converted to a humidity reading.

Wind speed and direction are typically measured using a cup anemometer equipped with a wind vane, or using an ultrasonic anemometer. Ultrasonic anemometers have no moving parts and simultaneously measure both the wind speed and direction (including its vector components).

Equivalent Embedment Length - the length of embedded straight reinforcement that can develop the same strength as that which can be developed by a standard hook, or mechanical anchorage.

Erection Tolerances - tolerances related to the geometry of a component with respect to that stipulated on the drawings.

Evaluation - process to determine the load-carrying capacity of a structure.

Exceptional Loads - loads due to forces of nature or accidents that would not be expected to occur more than once in the life of a bridge.

Exposed Frontal Area - the net area of a body, member or combination of members as seen in elevation.
Commentary: In the case of a straight structure, the sum of the areas of all members including railings and deck system, as seen in elevation at 90° to the longitudinal axis. In the case of a structure which is curved in plan, as seen in elevation at 90° to an axis chosen to maximize wind effects.

Exposed Plan Area - the net area of an object as in the case of a superstructure, the plan area of the deck and that of any laterally protruding railings, members, or attachments.

Extrinsic Fabry-Perot Interferometric (EFPI) Gauge – type of gauge that uses a sensing element that is external to the optical fibre.
Commentary: The sensing element consists of two mirrors made of a semi-reflective coating deposited on the tips of optical fibres that have been spot fused into a capillary. The mirrors face each other and are separated by an air gap, or cavity. As white light generated by the readout unit travels through the cavity, multiple and interfering light beams are reflected back. Therefore, the original white light is separated into several wavelengths as it is reflected. The wavelengths of the reflected

light are a function of the distance between the two reflective mirrors. A white light cross-correlator contained in the readout unit converts the reflected light into the absolute strain.

Factored Load - product of a nominal load specified in the Code and the corresponding load factor.

Factored Resistance - the resistance of a component, connection, foundation or cross-section obtained by multiplying the nominal resistance with a resistance factor that is always less than 1.0.

Falsework - a temporary structure used to support another structure or a part thereof.

Fatigue - initiation or propagation of cracks caused by the repeated application of load.

Fatigue Life and Fatigue Life Estimation – a physical fatigue process where crack growth causes failure.

Fatigue Limit State - a limit state at which the effects of fatigue on the strength or condition of the structure are considered.

Fibre Optic Connections – optical fibre connectors are the means by which fibre optic cables are usually connected to peripheral equipment and other fibres.
Commentary: The connections between fibre optic cables require special handling, installation, and testing considerations. These connectors are similar to their electrical counterparts in function and outward appearance but are actually high precision devices.

In operation, the connector centers the small fibre so that its light gathering core lies directly over and in line with the light source (or other fibre) to tolerances of a few ten thousandths of an inch. Since the core size of a common 50-micron fibre is only 0.002 inches, the need for such extreme tolerance is obvious.

The fibres in a fibre optic cable are very delicate and are typically protected by a plastic tube. Loose buffer cables use a gel between the plastic tubes in multiple-fibre cables to make them waterproof. Tight buffer cables use layers of plastic and yarn over the plastic tube, which results in both a smaller cable diameter and maximum bending radius.

Fibre optic cable is also frequently used for networking and communication applications. There are three basic types of fibre used in fibre optic cables:
- plastic
- multimode
- single mode

Copper cables are sometimes used for the construction of a network backbone. A cable category designation is used to specify the transmission speed for copper cables in networking and communication applications.

Fibre Optic Sensor Strain Gauge - a type of sensor that consists of an optical fibre lead with a bare fibre optic sensor at one end, and a special connector to the readout unit at the other end.
Commentary: In this form, the fibre optic sensor is small in diameter and can be used for embedment in FRP sheets and bars.

FOS strain gauges have several characteristics that would make them useful for many bridge testing and monitoring applications. These characteristics include fast response, immunity to EMI/RFI noise sources and lighting, low attenuation of the sensor signal, and long-term durabilty.

In rehabilitation and repair situations, fibre optic sensors can be attached to or mounted on existing concrete structures where composite materials are used as reinforcing wraps. The sensors can be used to measure and monitor a variety of components, conditions, and environments. The sensors have no electronic driftng due to aging of sensors nor interference by EM wave.

Foil Strain Gauge – type of gauge that is generally attached to the surface of structural components and wired to readout units.
Commentary: As the component experiences strain, the change in length at the surface of the component is transmitted to the strain gauge through the connecting substances. From there, the corresponding signal is transmitted to the readout unit through the lead wires. A linear gauge, Pair gauge and a rosette gauge can all be used to take more than one reading from a strain gauge at the same time.

Force Balance Accelerometers – type of accelerometer used in structural and seismic monitoring applications.
Commentary: The principle of operation is similar to that for capacitive types of accelerometers, but on a much smaller scale. The force balance accelerometers typically use a soft pendulous suspension for the mass, and thus are relatively fragile. The servo force balance accelerometers are very suitable for DC and low frequency responses providing milli-g measurement capability.

Frequency Domain Transformation – expression of a function by its amplitude and phase at each component frequency, usually determined by Fourier analysis.
Commentary: This transformation allows the user to view a signal in the frequency domain. A frequency domain representation illustrates the different frequencies that comprise the signal, and the contributions from each frequency to the signal.

Geometry Monitoring – a form of monitoring that includes surveying with laser, global positioning systems, photogrammetry and remote sensing technologies.

Commentary: The most common objective of geometry monitoring is to track changes in the geometry of a structure as an indication of phenomena such as foundation displacements or changes in cable systems, etc.

Global Positioning System (GPS) - a world-wide radio navigation system composed of aerial satellites and corresponding ground stations.
Commentary: The GPS povides a means of measuring position or displacement that does not require the component that is being tested to be physically connected to a fixed reference location. This technology basically uses satellites as reference points to calculate positions. The working principle of the GPS involves triangulation of the location using radio signals from satellites. Depending upon the direction of measurment, GPS accuracy ranges from metres to centimetres.

Gust Effect Coefficient - the ratio of the peak wind-induced load on a structure or response of a structure, including both static and dynamic action, to the static wind-induced load or response respactively; also referred to as the gust coefficient.

Health – a term used to define the performance and integrity of the health aspect of a structure in relation to the reliability of the system to possess adequate capacity against any probable demands that may be imposed on it.
Commentary: Health is determined by the purpose of the structure and corresponding safety margins as indicated by evaluation.

Health Monitoring - is the tracking of any aspect of a structure's health.

High Speed Monitoring Regime (HSPR) – monitoring of speed with frequencies higher than 25Hz for each sensor up to 100 Hz.
Commentary: HSPR captures high-speed events that occur over a short time-window, such as large-amplitude vibrations, impact of overloaded trucks, incidents and accidents, and hazards such as impacts, blasts, fires and earthquakes. Measuring these events requires a different category of sensing and data-acquisition, other than slow-speed monitoring, and an event-based triggering strategy.

In the case of monitoring the impact of traffic and operational conditions on the health of the bridge, as well as for security purposes, continuous high-speed real-time monitoring of both video and data becomes necessary.

Idealization - the numeric representation of a structure or load for purposes of analysis or testing.

Inertial Based Inclinometer - is a common type of tilt meter most suitable for measuring rapidly changing angles.

Information Technologies (IT) – a term used to describe the entire spectrum of efforts related to the acquisition, processing and interpretation of data.

Commentary: IT includes sensing, data acquisition, preprocessing, communication and control, transmission and synchronization, quality testing, post-processing, analysis, display and visualization, database archival and management, and interpretation for decision-making.

Linear Variable Differential Transducer (LVDT) - type of sensor used for measuring displacements.
Commentary: LVDTs consists of a hollow metallic casing in which a shaft, called the core, moves freely back and forth along the axis of measurement. The core is made of a magnetically conductive material, and a coil assembly surrounds the metallic shaft.

Inspection – on-site non-destructive examinations are carried out to establish the present condition of the structure.

In-depth Inspection – a more detailed inspection usually performed as a follow-up to a routine inspection to identify any deficiencies found.

Live Load - a load imposed by vehicles, pedestrians, equipment, or components that are subject to movement.

Load Effect - any effect on, or response of a structural component due to loads, forces, imposed deformations, or volumetric changes.

Load Factor - a factor applied to loads that takes into account variability, lack of precision in analysis for load effects, and reduced probability of loads from different sources acting simultaneously.

Load-sharing System - a system of members comprising two or more essentially parallel members so arranged or connected that they mutually support the load and deflect together by approximately the same amount.

Localized Nondestrstructive Evaluation (NDE) - a term used to designate technologies that have been developed for "seeing through or probing through" a structure to detect conditions and characteristics at the "local level". In addition to the in-situ techniques, material sampling for testing in the laboratory is included in this category.

Long Span Bridge - a bridge with an individual span in excess of 150 metres

Long-term Deformation - time-dependent deformation in soil or rock that occurs as a result of consolidation or creep, or both.

Long-term (life-cycle) Monitoring - continuous monitoring of a strucutre is considered "long term" when the monitoring is carried out over a period of years-to-decades, preferably for the life cycle of the structure.

Commentary: This type of monitoring is the result of recent advances in sensing, data-acquisition, computing, communication, data and information management, all of which have been integrated through internet technologies.

Measurement Calibration – a process used to check the integrated measurement system (the sensors, data acquisition and communication components) under controlled or known conditions, and to calibrate and verify the integrated measurement system on the actual structure.
Commentary: A thorough measurement calibration program is recommended for any application in order to identify and evaluate the possible sources of error.

Medium Span Bridge – a bridge with a span less than 125 ms, but greater than 20 ms.

Natural Frequency - the frequency of vibration of one of the natural modes of a bridge, expressed as cycles per second, being the inverse of the natural period.

Natural Period - the duration of one complete cycle of free vibration of a normal mode of vibration of a structure.

Nondestructive Dynamic Controlled Test – a type of test that can range from recording dynamic strains to estimating the fatigue-critical aspects of the loading environment.

Nondestructive, Static Controlled Testing - a short-term static test that may last from hours to weeks.
Commentary: Involves applying controlled loads and/or measuring ambient inputs to a bridge while measuring corresponding responses.

On-line analytical processing (OLAP) – type of processing that provides the architecture for organizing and analyzing data.
Commentary: A multidimensional database with an OLAP service provides a means to pre-analyze data as well as providing a foundation and structure for an efficient data mining process. A database system with data mining capacity may also take advantage of decision tree theory, neural networks, and rule-based expert systems.

Passive Resistance - the reaction occurring as a result of the movement of a retaining structure, footing, or pile toward backfill, soil, or rock.

Pedestrian Bridge - a bridge that provides a walkway primarily for the passage of pedestrians.

Pedestrian Load - the load due to pedestrians on a bridge.

Periodic Monitoring - is conducted to investigate any detrimental change that might occur in a structure or to its repairs. Periodic monitoring includes static and dynamic testing.

Permanent Loads - loads that do not vary unless physical changes are made to the bridge.

Piezoelectric Accelerometer – type of sensor that uses solid-state strain gauge elements that are physically attached to cantilever beams and electrically connected to a Wheatstone bridge circuit. Vibratory motion causes stress in the beams, which in turn causes a proportional change in the resistance of the strain gauge elements. *Commentary:* The piezoelectric accelerometer is the most common type of accelerometer. The primary sensing element is a piezoelectric element constructed in such a way that when stressed by vibratory forces a proportional electrical signal is produced.

Piezoelectric accelerometers with a charge output contain no internal integrated electronics, therefore the output signal requires conditioning by an external signal conditioner. Piezoelectric accelerometers with a voltage output contain internal signal processing electronics that permit greater design flexibility. These sensors require constant current signal conditioners and produce an output signal that can be transmitted over long cable lengths without significant losses. These accelerometers are suitable for measuring the long duration pulses found in transportation vibration, automotive crash studies and blast testing.

Proof Load - is a term used to describe the maximum load of a given configuration that a bridge has withstood without suffering any damage.

Proof Test – a test used to establish the safe load-carrying capacity of a bridge. *Commentary:* Proof-load tests should be conducted with only enough instrumentation to capture the responses of all of the critical elements.

Prying Action - additional force introduced into fasteners as a result of the deformation of parts that they connect.

Pull Back Test - type of test that can be conducted by using cables anchored in the ground or to a fixed object to pull a structure laterally, and then releasing the cables suddenly.

Rehabilitation - a modification, alteration, or improvement to the existing condition of a structure or bridge subsystem that is designed to correct deficiencies for a particular design life and live load level.

Reliability Index or Safety Index - a numerical measure of the reliability of a structure or its components to withstand loads.

Remaining working life – period of time that an existing structure is intended or expected to operate with planned maintenance.

Resistance Factor - a factor applied to the nominal resistance of a component at the ultimate limit state, taking into account the variability of material properties and

dimensions, workmanship, type of failure, and uncertainty in the prediction of the resistance.

Resistance Temperature Detector (RTD) - type of sensor used to measure temperature.

Reynolds Number - the ratio of inertial forces to viscous forces of a fluid.

Routine Inspection – a visual inspection of a structure.

Sensor - a device that converts energy from one form into another. The input energy to the sensor represents the physical phenomena being measured.
Commentary: The input to the sensor is referred to as the measurand, and the output is referred to as the measurement. Sensors can measure absolute values of, or changes in, strains, deformations, accelerations, temperature, moisture, acoustic emissions, time, electric potential or load.

Service Life - the number of years a structure is intended to be in use.

Serviceability Limit State – the state in which a structure no longer satisfies operating requirements and has been determined not fit for the intended purpose of the structure.

Shape Factor - the ratio of the area of the loaded face of a bearing and the area of an elastomeric layer around the perimeter of the bearing which is free to bulge.

Short Span Bridge – a bridge with a span of up to 20 ms.

Short-term Deformation - the deformation in soil or rock that occurs upon the application of a load.

Signal Processing – a processing system, which includes data filters, frequency domain transformations, statistical analysis and correlation analysis.

Slow-Speed Monitoring Regime – a system for monitoring speed with a frequency of less than 1.0 Hz for each sensor.
Commentary: This type of monitoring regime is suitable for intermittently monitoring fabrication, erection and construction or retrofit effects. This monitoring regime measures and documents the resulting displacements, deformations, and intrinsic forces, both for controlling the construction of the retrofit process and for capturing the initial conditions of the bridge for long-term health monitoring

Span - the horizontal distance between the centrelines of adjacent piers or abutments; or, where bearings are provided, between bearing centrelines; or, for rigid frames, including box culverts, the clear opening width.

Static Test - for the purpose of bridge testing, static loads are considered to be those loads that are brought onto or placed on the bridge very slowly, so as not to induce dynamic effects in the bridge.
Commentary: In cases of testing with vehicles, the vehicles should be brought on the bridge at a crawling speed.

Stress History Test - a test that establishes the distribution of stress ranges in fatigue-prone components of a bridge.
Commentary: The data, continuously obtained for a short time due to the passage of vehicles on the bridge, helps establish the fatigue life of the bridge.

Stress Range - the algebraic difference between the maximum and minimum stress at the fatigue limit state, where tensile stress has the opposite sign to compressive stress.

Structural Health Monitoring (SHM) – a type of system that provides information on demand about any significant change or damage occurring in the structure.

Suspension Bridge – a bridge with two towers and a suspended deck structure. The deck of the suspension bridge merely hangs from suspenders, and must only resist the bending and torsion caused by live loads and areodynamic forces.

Temperature Sensor – sensors that measure temperature.
Commentary: There are a wide variety of temperature sensors available. Three types commonly used in civil engineering applications are: resistive, vibrating wire;,and fibre optic temperature sensors.

Tilt Meter – an instrument that measures the rotation of a test specimen with respect to a datum represented in general by the gravity vector. Tilt meters are often used as part of the permanent instrumentation in bridge testing and monitoring applications.

Traffic Load - the load due to vehicles on a bridge.

Traffic Signal - a complete signal device consisting of traffic lights and housing.

Transitory Loads - a load due to traffic or equipment on the structure, or the seasonal effects of nature.

Transmission Control Protocal / Internet Protocol (TCP/IP) – a common communication protocol that is widely responsible for the rapid development and stability of Internet based technologies.
Commentary: This communication protocol has gained acceptance for uniform data transfer and communication. Numerous interfacing components for hardware are available that permit data acquisition components and some sensors to be directly connected to a network. In such cases, the data is usually transferred across the network using the TCP/IP protocol.

Unfactored Resistance - the resistance of a component or connection based upon specified material properties and nominal dimensions and calculated in accordance with the appropriate Code.

Upgrading – modifications to an existing structure to improve its structural performance.

Vibrating Wire (VW) Strain Gauge – a type of sensor that is relatively bulky (usually larger then 100 mm in length) and is produced for embedment in concrete or attaching to the surface of components.
Commentary: This type of gauge measures strains using the relationship between the strain and the natural frequency of vibration for a tensioned wire. The VW strain gauge has a well-established record of excellent performance and long-term reliability in numerous geotechnical and bridge monitoring applications. It is very stable and can be monitored continuously for long periods of time without any zero drift. VW strain gauges are most suitable for measuring static or slowly varying strains. They are not suitable for high-speed measurements.

Surface strain gauges can be welded, bolted or bonded to the material. Embeddable strain gauges can be directly placed in concrete or cast into a concrete briquette before being placed in their final position.

Vibration Sensitivity Damage – global structure properties affected by local damage.
Commentary: The change in global properties may be difficult to identify unless the damage is very severe or the measurements are very accurate.

Wavelet Analysis – a tool for analyzing localized variations of power within a time series.

Weight-In-Motion (WIM) System - is a system that consists of weight pad and loop detectors that is designed to collect data for traffic monitoring and characterization, engineering analysis, and weight enforcement.
Commentary: Installation and calibration of WIM systems are specified in ASTM standard (ASTM E1318-94). The ASTM standard also classifies a WIM system as Type I, Type II, Type III, or Type IV based on the data items measured. The items measured for each vehicle crossing the WIM scales that are relevant for bridge health monitoring applications typically include speed, number of axles, axle spacing, and axle weight.

Wireless Connection – a type of joint used in devices that are widely available for common interoffice use or for building-to-building type communication and networking applications.
Commentary: Most wireless devices currently permit maximum transfer speeds of 10-11 Mbps. The local geography, topography and other site-specific characteristics determine the effectiveness of a wireless communication connection. A site survey is required to determine whether a wireless implementation is possible for a given application.

Wireless Transmission System - is a portable microchip data acquisition system that accommodates transmission via radio frequency, internet or via satellite.

Abbreviations

AADT............ Average Annual Daily Traffic
AASHTO ...... American Association of State Highway and Transportation Officials
ADT .... Average Daily Traffic
ADTT .... Average Daily Truck Traffic
ASTM............ American Society for Testing and Materials
CHBDC......... Canadian Highway Bridge Design Code
DAQ .... data acquisition
DAS............... data acquisition system
DCDT........... direct current differential transformer
DLA .... dynamic load allowance
FBG.............. fibre bragg grating
FOS .... fibre optic sensor
GPS .... global positioning system
HSMR .... high speed monitoring regime
LVDT............ linear variable differential transducer
NDE .... nondestructive evaluation
OLAP .... on-line analytical processing
RTD.............. resistance temperature detector
SHM .... structural health monitoring
TCP/IP........... Transmission Control Protocol / Internet Protocol
VW .... vibrating wire
WIM............. weight-in-motion

Notations

α_L.................. live load factor used during calculation of proof loads for bridges.
β.................. reliability or safety index
C_e.................. the wind exposure coefficient
C_f.................. a correction factor used to adjust the F value for longitudinal moment and longitudinal vertical shear
C_g.................. the horizontal wind drag (gust) coefficient
C_h.................. the horizontal wind drag coefficient
C_p.................. the external pressure coefficient, averaged over the area of the surface considered.
C_{pi}.................. the internal pressure coefficient
C_v.................. the vertical wind load coefficient
E.................. modulus of elasticity, MPa
E_c.................. the modulus of elasticity of concrete
E_s.................. the modulus of elasticity of steel
F_h.................. the horizontal wind load per unit exposed frontal area, Pa
G.................. shear modulus, MPa
g.................. acceleration due to gravity, m/s^2
G_c.................. the shear modulus of concrete
G_s.................. the shear modulus of steel
K.................. all strains, deformations, displacements, and their effects, including the effects of their restraint and those of friction or stiffness in bearings. Strains and deformation include those due to temperature change and temperature differential, concrete shrinkage, differential shrinkage, and creep; but not elastic strains.
k.................. factor for calculation of load factor for wind effects as determined by wind tunnel tests
n.................. the natural frequency of vibration, Hz; or the number of design lanes on a bridge
Q.................. the applied load, kN
q.................. the applied wind pressure, kPa
p.................. the specified external pressure acting statically and in a direction normal to the surface either as a pressure directed towards the surface or as a suction directed away from the surface
V.................. the hourly mean wind speed, m/s; or wind load on traffic; or the seismic zonal velocity ratio (dimensionless)
V_{ref}.................. the reference wind velocity at deck height, m/s
V_w.................. the design speed of a highway, km/h; or water velocity at the design flood, at SLS and ULS, m/sw
W.................. the total dead load weight of a structure engaged in vibration, including asphalt, etc., N; or wind load on structure
W_c.................. bridge deck width, m
W_e.................. design lane width, m

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