Designation: F3079 – 14 (Reapproved 2020)

Standard Practice for Use of Distributed Optical Fiber Sensing Systems for Monitoring the Impact of Ground Movements During Tunnel and Utility Construction on Existing Underground Utilities[1]

This standard is issued under the fixed designation F3079; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice specifically addresses the means and methods for the use of distributed optical fiber sensors for monitoring ground movements during tunnel and utility construction and its impact on existing utilities.

1.2 This practice applies to the process of selecting suitable materials, design, installation, data collection, data processing and reporting of results.

1.3 This practice applies to all utilities that transport water, sewage, oil, gas, chemicals, electric power, communications and mass media content.

1.4 This practice applies to all tunnels that transport and/or store water or sewage.

1.5 This practice also applies to tunnels that carry the utilities in (1.3), water for hydropower, traffic, rail, freight, capsule transport, and those used for storage.

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E2586 Practice for Calculating and Using Basic Statistics

2.2 *Other Standards:*

IEC 61753-1 Fibre Optic Interconnecting Devices and Passive Components Performance Standard—Part 1: General and Guidance for Performance Standards[3]

IEC 61757-1 Fibre Optic Sensors—Part 1: Generic Specification[3]

COST Action 299 "FIDES" Optical Fibres for New Challenges Facing the Information Society[4]

ITU-T G.652 Characteristics of a Single-mode Optical Fibre and Cable[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *accuracy*—the closeness of the measured value to the true or the ideal value of the parameter being measured. Accuracy represents the difference between the measured result and the true value and is affected by both bias and precision.

3.1.2 *attenuation*—the decrease in power of a signal, or light wave, from interaction with the propagation medium. The decrease usually occurs as a result of absorption, reflection, diffusion, scattering, deflection, dispersion or resistance.

3.1.3 *attenuation budget (also called optical power dynamic range and link budget)*—the maximum cumulative one-way or

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, https://www.iec.ch.

[4] For additional information, visit http://www.cost.eu.

[5] Available from International Telecommunication Union (ITU), Place des Nations, 1211 Geneva 20, Switzerland, http://www.itu.int.

two-way power loss between the interrogator and the measurement point that allows a measurement with a specified performance.

3.1.4 *bias*—the difference between the measured result after averaging and the 'true' value. The true value can be obtained either by measuring a reference standard maintained by the national standard organizations or by using a traceable measuring instrument.

3.1.5 *bofda*—Brillouin optical frequency domain analysis.

3.1.6 *bofdr*—Brillouin optical frequency domain reflectometry.

3.1.7 *botda*—Brillouin optical time domain analysis.

3.1.8 *botdr*—Brillouin optical time domain reflectometry.

3.1.9 *characteristic frequency and/or wavelength at reference temperature (Brillouin technologies)*—the wavelength that characterizes the sensor response at reference temperature as monitored by the interrogator. As Brillouin frequency varies with wavelength of the light source, this also changes the temperature and strain coefficients for various sensing fibers. Therefore, the characteristic frequency and the wavelength at a specified reference temperature and at zero strain are usually provided by the producers.

3.1.10 *cladding*—optical transparent material over the core of the fiber optic cable, with a refractive index lower than that of the core, to provide total internal reflectance.

3.1.11 *connector*—coupling device that permits a signal to pass from one optical fiber to another.

3.1.12 *connector insertion loss*—the power loss due to the insertion of a connector between two elements.

3.1.13 *contractor*—usually, the entity in charge of construction of the new tunnel or other infrastructure that may impact the utility.

3.1.14 *core*—the primary light-conducting region of an optical fiber. The refractive index of the core is higher than its cladding, the condition necessary for total internal reflection.

3.1.15 *cross-sensitivity*—the unwanted change of measured result due to the influence of physical factors other than the measured parameters.

3.1.16 *distributed optical fiber sensor system (DOFSS)*—a system using optical fiber cable as a sensor, without discrete elements such as wound mandrels or fiber Bragg gratings, that is sensitive over its entire length to deliver spatially continuous and resolvable data on the desired measured parameters.

3.1.17 *drift*—a slow change in time of the monitoring characteristics of the measurement system.

3.1.18 *durability*—a quality of a manufactured component of a measurement system or of the entire measurement system measured by how well it withstands a sustained period of specified operation.

3.1.19 *engineer*—the licensed professional engineer designated by the owner/operator of the utility or the tunnel to represent the owner's/operator's interests during the ground movement monitoring process.

3.1.20 *failure criteria of the sensor*—the measurement uncertainty due to overstressing, overheating and other factors leading to results or data that are unreliable.

3.1.21 *gauge length (GL)*—the length of the fiber that contributes to the measured output value of a single channel.

3.1.22 *life expectancy*—a period of time during which the measuring system or its components are expected to operate according to its specifications for defined conditions.

3.1.23 *limiting conditions*—the extreme conditions that a measuring instrument is required to withstand without damage, needing to switch off or degradation of specified characteristics when it is subsequently operated under its rated operating conditions.

3.1.24 *linearity*—the tolerance to which the transfer response characteristics of a measurement system (scale factor) approximates a straight line over the sensor range of the system. For Brillouin sensors, it means that the range of temperature or strain should be within the Brillouin frequency which is linearly proportional to the strain or temperature. For Optical Frequency-Domain Reflectometry (OFDR) systems it means that the wavelength or frequency shift is linearly proportional to temperature or strain over certain length.

3.1.25 *link budget (also called optical power dynamic range or attenuation budget)*—the maximum cumulative one-way or two-way power loss between the interrogator and the measurement point that allows a measurement with a specified performance.

3.1.26 *location accuracy*—the estimated location of a measurement or other system output, such as a detection report, minus the true location of the stimulus that generated the measurement or output.

3.1.27 *measurement range*—a set of values of measured parameters for which the error of a measuring instrument is intended to fall within specified limits.

3.1.28 *measuring spatial resolution*—the minimum distance over which the DOFSS is able to detect the value of the measured parameter, such as strain or temperature, averaged over this minimum distance, within the specified uncertainty.

3.1.29 *measuring time*—the required time interval needed to obtain a measurement within the specified uncertainty, the spatial resolution, and the system range, including any time required for data post-processing.

3.1.30 *noise*—the random variation in the measurement result unrelated to the measured parameter. It primarily affects the precision of measurement.

3.1.31 *operating temperature range of the measurement unit*—the range of temperatures over which, the measurement unit can collect data on the parameters of interest, without losing its capacity for performance and reliability.

3.1.32 *operator*—the firm hired by the owner to perform operation and maintenance of the tunnel or utility.

3.1.33 *optical fiber sensing cable*—cable formed using one or more strands of optical fiber to sense physical parameters and/or transmit data.