GLOSSARY

Accelerometer: instrument to measure seismic acceleration. It can be *analog* if ground acceleration is reproduced by a mechanical instrument on a physical support, typically paper or photographic film, and it is digitized at a later stage, or *digital* if it is typically based on either electro-magnetic or force-balance transducers. The electric signal is then properly conditioned, sampled and digitized. The digital instruments are operating from about the mid-80s. All data included in ISMD are recorded by digital accelerometers. The most representative parameters defining the characteristics of the recording instrument response are as follows: sensor undamped natural vibration frequency (frequency), sensor damping coefficient with respect to critical (damping), frequency band for which the sensor gives a flat response (frequency band), generator constant of the sensor (gain), smallest signal that can be resolved by the sensor (sensitivity), maximum signal that can be resolved by the sensor (full scale), number of bits of the recorder (number of bits).

Arias Intensity: is an integral parameter of severity of ground motion.
Introducing the function of motion intensity:

$$I(t) = \frac{\pi}{2g}\int_0^t a^2(\tau)d\tau$$

where $a(t)$ is the acceleration at time t and g the gravity acceleration. The Arias Intensity is the maximum value of this function, i.e. $I_A = I(T_d)$ where T_d is the accelerogram total duration. Arias Intensity is dimensionally a velocity (cm/s).

AUTO: is the acronym used in ISMD tables to indicate not-revised data (automatically processed) for earthquake with magnitude < 3.5. Data for earthquakes with magnitude ≥ 3.5 are instead processed usually within 24 hours after the event origin time by an expert operator in order to convert AUTO in MAN (revised data). AUTO data are provided just in SAC format (raw data, unit: counts).

Baseline correction: is a procedure to correct certain types of long period disturbances on accelerometric signals. The simplest procedure is to subtract from the accelerogram its average value (which theoretically should be zero to ensure a zero velocity at the end of the seismic motion). In the case of digital accelerograms with pre-event, it is possible to remove from the entire signal the average value calculated only on the pre-event portion. For detail see the ISMD user manual downloadable from the ISMD web site.

Component: one of the three spatial components of the seismic motion. The two horizontal components, orthogonal to each other, are denoted by N (North-South) and E (East-West). The vertical component is denoted by Z.

Dispersion curve: in physical sciences, dispersion relations describe the effect of dispersion in a medium on the properties of a wave traveling within that medium. A dispersion relation relates the wavelength or wavenumber of a wave to its frequency.

Duration: is defined as the time interval of the accelerometric signal in which the seismic motion is *significant*. To this aim two definitions are often used:
a) duration based on the exceedance of a threshold value (bracketed duration): a threshold is fixed, typically 0.05 *g*, above which it is deemed that the motion has relevance for engineering purposes; the duration is the time interval between the first and the last exceedance of this value.
b) duration based on the motion intensity: the Arias Intensity function *I(t)* is calculated (see Arias Intensity), and normalized with respect to its maximum value I_{max}; the duration corresponds to the time interval *t2-t1*, where *I(t1) = 0.05 and I(t2) = 0.95* (i.e between the 5% and 95% of the total energy of the target time history).

Earthquake origin time: the origin time indicates the date and time at which start breaking along the fault plane. Note that large earthquakes can have rupture processes that last many tens of seconds. In the tables of the ISMD website the earthquake origin time is provided in UTC (Coordinated Universal Time, the time zone of reference from which all other time zones in the world are calculated). Seismologists use UTC to conform to a single measurement time and thus avoid confusion caused by local time zones and from daylight saving. The Italian local time is UTC +1 hour if it is during the winter time and UTC +2 hours when daylight saving time is in effect.

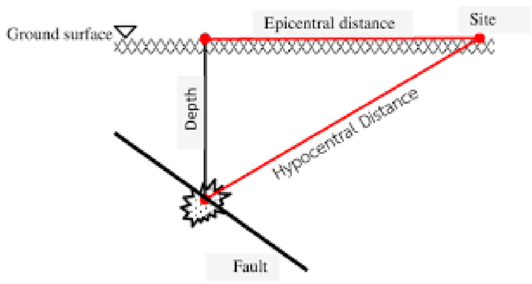
Epicenter location (latitude and longitude): an earthquake begins to rupture the crust at the focus, defined as the point at depth where it begins the breaking of rocks or sliding on the fault and from which seismic waves start propagating in all directions. The hypocenter is defined by a position on the surface of the Earth (epicenter) and by a depth below this point (focal depth).
The coordinates of the epicenter are expressed in units of latitude and longitude. The latitude is the number of degrees north (N) or south (S) from the equator and ranges from 0 to 90 at the equator to the poles. Longitude is the number of degrees east (E) or West (W) from the prime meridian that runs through Greenwich, England. The longitude ranges from 0 (Greenwich) to +/- 180 depending on whether E or W of Greenwich, respectively. The coordinates are given in the WGS84 reference system.

Earthquake Depth: the depth of the hypocenter is the point at depth where it begins the breaking of rocks or the sliding on the fault. This depth is relative to mean sea level. Sometimes, when the depth is poorly constrained by the available seismic data, the seismologist in seismic surveillance center sets the depth to a fixed value. For example, 10 km is often used as a default depth for earthquakes that are thought to be superficial, when the depth cannot be calculated in a satisfactory manner by the data.

EC8 soil class: the seismic site classification is based on the stratigraphic and dynamic properties of the soil profile. Site classes are defined according to the Eurocode 8 as follows:
Class A: rock or other similar geologic formation, including 5 m (maximum) of surface weathered material. Vs,30 > 800 m/s (see Vs,30);
Class B: very dense sand or gravel, or very consistent clay, in soil deposits at least several tens of meters depth, characterized by a gradual increase of dynamic properties with depth. 360 m/s < Vs,30 < 800 m/s.;
Class C: medium dense sand or gravel, or consistent clay, in deposits with depth between several tens to hundreds meters. 180 m/s < Vs,30 < 360 m/s.;
Class D: loose to medium dense non-cohesive soil deposits (with or without cohesive soil layers), or medium consistence cohesive materials. Vs,30 < 180 m/s.;
Class E: soil profile consisting of a shallow alluvial layer with Vs values typical of C or D class, and thickness between about 5 m and 20 m, lying on a material with Vs,30 > 800 m/s.;

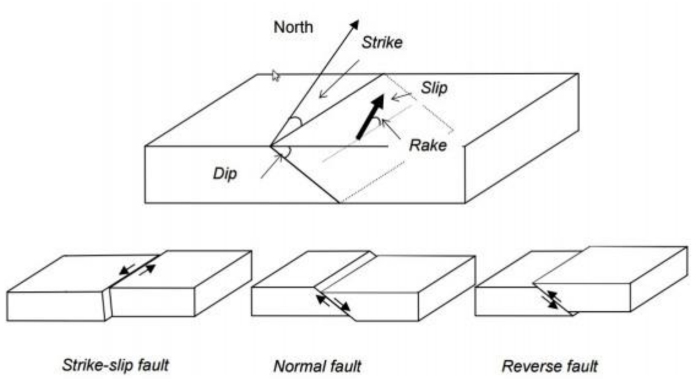
Class S1: deposits consisting of - or containing one layer at least 10 m thick - high plasticity clays/silts (P1 > 40) with a high water content;
Class S2: soil deposits susceptible to liquefaction, or sensitive clays, or any other profile which is not included in the A-E or S1 classes

Epicentral distance: is defined as the distance on the ground surface between the site and the earthquake epicenter. This latter is defined as the point on the earth surface placed exactly on the vertical passing from the hypocenter (or focus), where the rupture takes place. The distance between the site and the earthquake hypocenter is denoted as hypocentral distance.



Event: is the considered earthquake. It is characterized by the geographical coordinates of the epicenter (see *Epicenter location*) and by the hypocentral depth (see *Hypocentral Depth*), and by the occurrence date (see *Earthquake origin time*). Other distinctive properties of the seismic event are the magnitude (see *Magnitude*) and the focal mechanism (see *Focal Mechanism*).

Fault: an earthquake occurs when a volume of rock, subject to deformation mechanisms of tectonic origin, ruptures along a weak surface, which is denoted as fault, resulting in a relative displacement between the two blocks of rock separated by the fault. To locate the fault plane position and the slip direction, the following definitions are usually considered:
Strike: clockwise angle formed by the intersection of the fault plane with the ground surface and the North direction;
Dip: angle formed by the fault plane and the horizontal direction;
Rake: angle formed, with respect to the intersection of the fault plane with the surface, by the vector defining the relative displacement (slip) between the block above the fault plane (hanging wall) and the one below (foot wall).
A simple classification (rakes angles within 30° of horizontal are strike-slip, angles from 30° to 150° are reverse, and angles from −30° to −150° are normal) is used to classify style of faulting.



Filter: Raw data (see *Raw data*) collected by the recording instrument are generally processed for the following purposes: a) correction with respect to the instrument characteristic curve; b) correction of the high and low frequency errors; c) filtering, in order to highlight or eliminate a particular frequency band. Such operations are often performed in the frequency domain, using filtering algorithms based on the Fast Fourier Transform (FFT), and schematized by the following procedure:

1. The FFT of the original accelerometric record is performed:

$$a(t) \leftrightarrow A(\omega)$$

2. The instrument characteristic curve H(ω) is removed. Recalling that A(ω) = H(ω)·U(ω), the Fourier transform of the record is obtained, in which the instrument response is removed:

$$U(\omega) = \frac{A(\omega)}{H(\omega)}$$

3. The filter is applied in the frequency domain by multiplying the function U(ω) times the filter B(ω), either high-pass, or low-pass or band-pass, depending on the type of disturbance to eliminate or of the frequency band to highlight:

$$U_c(\omega) = U(\omega)\, B(\omega).$$

4. The inverse Fourier transform is computed, to obtain the corrected signal in the time domain:

$$u_c(t) \leftrightarrow U_c(f)$$

An acausal band-pass second order Butterworth filter has been used to filter the ISMD accelerometric data. The frequency band was selected in each case based on the earthquake magnitude (see ISMD user manual downloadable from ISMD web site).

Focal Mechanism: represents the geometry of fault rupture during an earthquake (see *Fault*). It is studied based on the polarity of the first arrivals of *P* and *S waves* recorded by a network of far field seismic stations. 3 basic types of focal mechanisms are distinguished (see Fig. in *Fault*):

strike-slip: the blocks of rock on either side of the fault slide horizontally, parallel to the strike of the fault;

reverse: the earth's crust is in compression along a dipping fault plane, where the hanging wall moves upwards relative to the footwall;

normal: the earth's crust is in extension along a dipping fault plane, a geologic fault in which the hanging wall has moved downward relative to the footwall.

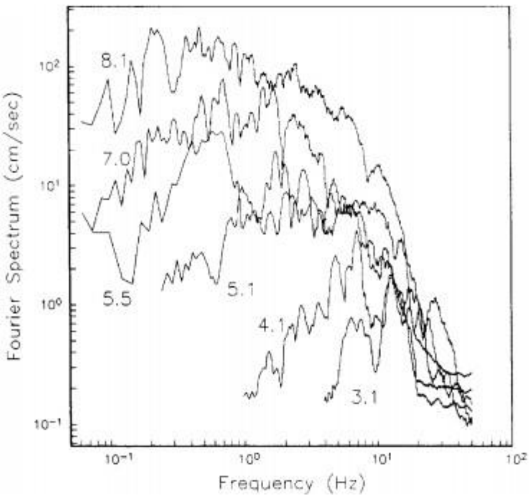
Fourier spectrum: The Fourier transform of the signal a(t) is defined as follows:

$$A(f) = \int_{-\infty}^{+\infty} a(t) e^{-i2\pi ft}\, dt$$

Generally *A(f)* is a complex function. The modulus of the Fourier transform is denoted as Fourier Spectrum of the signal *a(t)*:

$$|A(f)| = \sqrt{R^2 + I^2}$$

where *R* and *I* are the real and imaginary part of *A(f)*, respectively.



In Fig. example of Fourier Spectra of increasing magnitude accelerograms, recorded in 1985-1986 by digital instruments located on the Pacific coast of Mexico (Guerrero network).

f_0: is the fundamental frequency (f0) characterizing each recording site. The f_0 value is provided considering the results of the microtremor *HVSR*, together with the geological and the geomorphological conditions of the site. Usually f_0 corresponds to the lowest frequency peak with amplification *(A)≥2*. In case of multiple peaks in a broad range of frequencies, the value of f0 is selected based an expert judgment. f0 'none' indicates a flat response of the noise HVSR (A≤2) in the frequency range 0.1-10 Hz (see *Technical note* at *Station home page* for explanation).

Geology: for each recording site, the geological map at scale 1:100.000 (*Italian Geological Maps*) is provided with topographic IGM base at scale 1:25.000. If available, also detailed geological maps at scales 1:50.000 (CARG project) are provided. ISMD geology class are defined as: *sedimentary rock*, *sedimentary cover*, *metamorphic rock*, *igneous rock*, *debris slope*, *volcanic deposit*, *morainic deposit* (see *Technical note* at *Station home page* for explanation)

Hypocentral depth: is the distance between the hypocenter and the epicenter of the earthquake (see Fig. in *Epicentral Distance*).

Housner Intensity (or response spectrum intensity): is defined as follows:

$$SI(\xi) = \int_{0.1}^{2.5} PSV(T,\xi)dT$$

where *PSV* is the pseudo-velocity response spectrum (see Response Spectrum), *T* and ξ are the structural natural period and damping, respectively. For ISMD data, the Housner Intensity was calculated considering ξ *= 5%*. This parameter of seismic motion severity is related to the potential damage expected from the considered earthquake, since the majority of structures have a fundamental period of vibration in the range between *0.1* and *2.5 s*. The *Housner Intensity* has the same units as displacement (cm).

HVSR: horizontal to vertical spectral ratio (see *Technical note* at *Station home page* for explanation).

Magnitude: seismologists indicate the size of an earthquake in units of magnitude. There are many and different ways in which magnitude can be measured from seismograms. Each method works only on a limited interval of magnitude and epicentral distances, and types of data (e.g. types of seismometers). Some methods are based on volume waves (traveling deep within the structure of the Earth), some based on surface waves (traveling mostly along the surface layers of the Earth) and some based on completely different methods. However, all the methods are designed to link up well beyond the range of magnitude which are reliable. In most cases, the first estimate of the magnitude provided by INGV seismic surveillance is the Richter local magnitude M_L. For events with a magnitude greater than about 3.5, if data are available, we calculate the focal mechanism with the technique of Time Domain Moment Tensor (TDMT, http://cnt.rm.ingv.it/tdmt) to obtain estimates of the Moment magnitude M_w.

The local magnitude *(M_L)*, or Richter magnitude, is defined as follows:

$$M_L = log A - log A_0$$

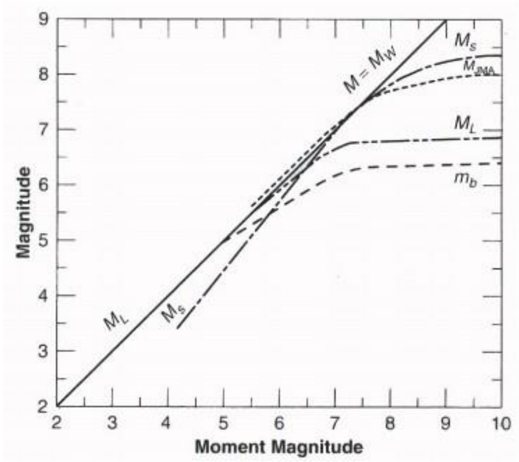
A=peak amplitude, in mm, of the track recorded by a *Wood-Anderson (WA)* seismograph at a given distance; *A_0=amplitude* corresponding to the reference earthquake ("zero") at the same distance. The Richter magnitude scale is logarithmic, so an increase of a unit of M_L implies an increase of 10 times in the motion amplitude (the total amount of energy released by the earthquake increases 32 times for each unit of magnitude). Therefore, in moving from ML = 4 (low intensity earthquake) to M_L = 7 (strong intensity earthquake), there is an increase in amplitude of 1000 times. One limitation of the magnitude scale M_L is the tendency to saturation for magnitude around 7.0-7.5; this depends on the bandwidth limitations of the *WA* seismograph, which do not make it suitable for recording the long period oscillations generated by large earthquakes. The moment magnitude is instead defined from the seismic moment, which is defined as:

$$M_0 = G\overline{\Delta u}A$$

where *G* is the shear modulus of the crustal material where the seismic rupture occurs, *A* the area of the rupture surface in the seismogenic fault, and $\overline{\Delta u}$ the average coseismic slip on the rupture surface. The seismic moment contains the most important physical parameters associated with the energy release during an earthquake. The moment magnitude is calculated based on the seismic moment as follows:

$$M_W = \frac{2}{3} log M_0 - cost$$

where *cost=10.7* if M_0 is measured in dyne·cm and *cost=6.0* if M_0 is measured in N·m. M_0 is a quantity that can increase indefinitely as the source and dislocation dimensions increase, so M_W does not saturate.
This concept is illustrated in the example reported in the figure below by the relationship between M_W and the other commonly used magnitude scales. This shows that, in practice, $M_W = M_L$ for $M_W \leq 6.2$ can be assumed.



Relationship between moment magnitude M_W and other magnitude scales, in particular the local magnitude M_L.

MAN: is the acronym used in the ISMD tables to indicate the revised data (earthquake with magnitude ≥ 3.5)

Morphology: this heading indicates the morphology of the site where the recording instrument is located. The following morphology types are distinguished: *relief*, *ridge*, *valley*, *gentle slope*, *plain*, *plateau* (see *Technical note* at *Station home page* for explanation)

Network: network denotes the accelerometric network operating the recording instrument. Each network include in ISMD is represented using the related FDSN (http://www.fdsn.org/networks/) code.

NTC18 soil class: the seismic site classification is based on the stratigraphic and dynamic properties of the soil profile. Site classes are defined according to the actual Italian anti seismic code provision (NTC18) as follows:
Class A: rock or other similar geologic formation, including 5 m (maximum) of surface weathered material. Vs,30 > 800 m/s (see Vs,30);
Class B: very dense sand or gravel, or very consistent clay, in soil deposits at least several tens of meters depth, characterized by a gradual increase of dynamic properties with depth. 360 m/s < Vs,30 < 800 m/s.;
Class C: medium dense sand or gravel, or consistent clay, in deposits with depth between several tens to hundreds meters. 180 m/s < Vs,30 < 360 m/s.;
Class D: loose to medium dense non-cohesive soil deposits (with or without cohesive soil layers), or medium consistence cohesive materials. Vs,30 < 180 m/s.;
Class E: soil profile consisting of a shallow alluvial layer with Vs values typical of C or D class, and thickness between about 5 m and 20 m, lying on a material with Vs,30 > 800 m/s.

PGA: the peak ground acceleration denotes the maximum ground acceleration recorded during the seismic shaking.

PGD: the peak ground displacement denotes the maximum ground displacement recorded during the seismic shaking. It is the maximum value of the record obtained by integrating twice the acceleration time history.

PGV: the peak ground velocity denotes the maximum ground velocity recorded during the seismic shaking. It is the maximum value of the record obtained by integrating once the acceleration time history.

Raw data (unprocessed, see *AUTO*): the unprocessed record is the signal coming from the recording instrument after the analog-digital conversion and transformed by calibration factors to the proper measurement units. This signal typically can contains instrumental errors in low and high frequency (noise or instrumental drifts), which are subsequently removed by the processing procedures. The raw data are provided in *SAC* format (https://ds.iris.edu/files/sac-manual/manual/file_format.html), unit: *counts*.

Revised data (processed, see *MAN*): in a processed data the disturbances present in the original signal at both high and low frequency have been removed or reduced. Two subsequent steps are employed in order to correct the low frequency disturbances: the baseline is removed in the time domain (see *Baseline Correction*), the accelerogram is high-pass filtered (see *Filter Correction*). In order to correct the errors at high frequencies, the accelerogram is low-pass filtered (see Filter Correction). Revised data (see *MAN*) are provided in ASCII format (unit: *gal*) for all earthquakes with magnitude ≥ 3.5 recorded on the Italian territory. The procedure is described in detail in the ISMD user manual, downloadable from the ISMD web site.

Region: in the ISMD tables there is shown the Italian municipality or the area where the earthquake occurred. This information is provided by the INGV-ONT *(http://cnt.rm.ingv.it)* and it is obtained by taking the Italian municipality of the City where the epicenter falls on the basis of Istat. The zones are areas in the sea very close to the coast, the border areas and all locations outside the national territory. The areas have been defined in a database created specifically by INGV.

Response Spectrum: provides the maximum response (in terms of relative displacement, relative velocity or absolute acceleration) of a harmonic 1 degree-of-freedom (*dof*) oscillator, subject to an arbitrary accelerogram, as a function of the structural period *Tn* and of the damping ratio ξ (usually a standard value equal to 5% of the critical damping is used, generally applicable to all structures). The maximum amplitude of the response is obtained by integrating the equation of motion of the harmonic oscillator:

$$\ddot{x}(t) = -\omega_n^2 y(t) - 2\xi\omega_n^2 \dot{y}(t)$$

where:
$y(t)$ is the relative displacement of the oscillator with respect to the ground
$\ddot{x}(t)$ is the absolute acceleration of the oscillator
ω_n is the oscillator natural circular frequency

The following definitions are introduced:

displacement spectrum (relative) $D(T_n,\xi) = \max_t |y(t)|$

velocity spectrum (relative) $V(T_n,\xi) = \max_t |\dot{y}(t)|$

acceleration spectrum (absolute) $A(T_n,\xi) = \max_t |\ddot{x}(t)|$

The pseudo-acceleration and pseudo-velocity spectra are also widely used in practice. They are defined as a function of the displacement spectrum as follows:

pseudo-acceleration spectrum: $PSA(T_n,\xi) = \left(\frac{2\pi}{T_n}\right)^2 D(T_n,\xi)$

pseudo-velocity spectrum: $PSV(T_n,\xi) = \left(\frac{2\pi}{T_n}\right) D(T_n,\xi)$

Sampling frequency: corresponds to the time step between two consecutive points of the record, which is obtained either directly from a digital instrument or from the digitization of the analog signal.

Seismic sequence: is a series of earthquakes occurring in the same region at close intervals of time. Typically a seismic sequence consists of a strong and severe seismic event (*mainshock*), possibly anticipated by a series of minor earthquakes (*foreshocks*), and always followed by many events of lower intensity (*aftershocks*).

Station: denotes the recording instrument (accelerometer) and its physical location. Each recording station can be identified by its network (see *Network*), an alphanumeric code, a name and its geographical coordinates.

Strong motion data: data recorded from an accelerometric station.

Topography: the following topographic categories are considered, according to the Italian Technical Norms for Civil Constructions (Norme Tecniche per le Costruzioni, 2018), close to those of the EC8 Part 5:
T1: plains, slopes and isolated hills with an average inclination $i < 15°$;
T2: slopes with an average inclination $i > 15°$;
T3: hills or mountains with a ridge width much smaller than the base width and average inclination $15° < i < 30°$;
T4: hills or mountains with a ridge width much smaller than the base width and average inclination $i > 30°$.

The topography classes are related to the morphology types (i.e. relief, ridge, valley, gentle slope, plain, plateau).

V_s profile: contains the information on the propagation velocity of *shear (S) waves* in the soil underneath or in the vicinity of an accelerometric station, as a function of depth. Typically the stratigraphic profile is defined by layers of varying thickness, each of them characterized by the corresponding shear waves velocity, expressed in m/s. The knowledge of the S-wave velocity is one of the most important parameters for the mechanical characterization of the site of interest, and its classification (see *EC8/NTC18 Soil Class* and *Vs,30*)

V_{s30}: is an average measure of the shear (S) wave velocity in the soil, within the first 30 meters of depth from the ground level. It is defined as follows:

$$V_{s30}= (30/\sum_{i=1,N})*(h_i/V_i)$$

where *hi* and *Vi* are the thickness (in m) and the shear wave velocity *Vs* (in m/s) of the N^{th} soil layers present within the first 30 m

Waveform: is the visual form of the recorded time history of wave motion. In ISMD the unprocessed acceleration time history (for $M_L<3.5$), the processed acceleration (for $M_L\geq3.5$), velocity and displacement (for $M_L\geq3.5$) are displayed, together with the acceleration and displacement response spectra plots (see *Response Spectrum*) in each event page.

References

Arias, A. (1970). A measure of earthquake intensity, in Seismic Design of Nuclear Power Plants, R. Hansen (Editor), M.I.T. press, Cambridge.

Comite' Europeen de Normalisation (CEN 2003) prEN 1998-1- Eurocode 8: design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for resistance. Part 1: General rules, seismic actions and rules for buildings. Draft No 6, Doc CEN/TC250/SC8/N335, January 2003, Brussels.

Housner, G.W. (1952). Spectrum intensities of strong-motion earthquakes, in: Proc. Symp. on Earthquake and Blast Effects Structures, C. M. Feigen (editors), Univ. California, Los Angeles, 21-36.

Ministero delle Infrastrutture e dei Trasporti (NTC 2018). Aggiornamento delle Norme Tecniche per le Costruzioni. Part 3: Categorie di sottosuolo e condizioni topografiche, Gazzetta Ufficiale n. 42 del 20 febbraio 2018.

Part of text and figures are adapted from Faccioli E. e R. Paolucci: "Elementi di Sismologia applicata all'Ingegneria", Pitagora, 2005. Some definitions are adapted from http://cnt.rm.ingv.it/en/help and from http://itaca.mi.ingv.it/static_italy_23/doc/glossary.pdf