Earthquake hazard and loss assessment is a relatively new lesson presented in these post graduate studies. The aim of the lesson is to present a procedure permitting the estimation of the loss due to earthquakes. This procedure takes into account, in a detailed manner, the different parameters affecting the loss assessment due to earthquake hazard and is based on the similar procedure used in the USA in order to calibrate the state policies against earthquake damage. The parameters integrated in a loss assessment procedure are the following:

- The estimation of the seismic hazard deals with the ground motion that is expected to affect the area under examination.
- The elements at risk parameter deals with the estimation of the number and type of the building structures, facilities and other socioeconomic units that are exposed to earthquake hazard at the given site.
- The vulnerability of each element at risk which presents the degree of damage expected for each level of earthquake hazard. In example for buildings this vulnerability can be presented in terms of the expected damage level for different levels of structural displacement

The above referred items can be combined in order to estimate the expected damage that will occur in the examined area. This total damage index is expressed as earthquake risk in units of cost which will be given either as the sum expected to be spent in order to recover from the hazard induced situation or as a percentage of the total replacement cost of the elements at risk. More analytically the earthquake risk is the product of the earthquake hazard with the elements at risk and the element vulnerability. The procedure to estimate the different parameters is called a loss assessment procedure. In the context of this lesson the aspects affecting each of the referred parameters will be presented as well as their estimation. In the figure the flowchart of the procedure is presented. As you can see each of the referred parameters is further subdivided. Since we will start with the estimation of the earthquake hazard each subdivision will be explained.

The earthquake hazard is subdivided in the following items:

a. Definition of the regional seismicity model
b. Selection of an attenuation model and
c. Site response

The regional seismicity model defines the regions that generate earthquakes at the periphery of a site under examination. Generally, several earthquake source zones are defined with their level of activity determined from both historical seismicity, if available, and an understanding of the underlying geological structures.

Attenuation models modify the earthquake with distance from the earthquake focus to give the characteristics of the earthquake vibrations below a site at bedrock level. Attenuation models are usually coupled with a site response model in order to adjust the earthquake ground shaking at a site for the influence of weathered rock and overlying soils on the propagating waves. These typically amplify the vibrations, thereby causing a greatly accentuated impact upon certain building types.

Seismic sources are usually identified as fault systems and are estimated through the identification of the regional seismic faults and their characteristics. In cases that this identification is problematic as, for instance, in the case of an extensively fractured earth crust in a region, the seismic sources can cover a whole area characterized by a background seismicity.

Since the knowledge of fault characteristics is indispensable for the identification of the whole hazard project, we shall start with their presentation.

Faults are areas of the earth's crust that have already been ruptured during past earthquakes and are susceptible to rupture in the future. Faults may range from several meters up to hundreds of kilometers. The presence of a fault does not necessarily denote future earthquake events since faults may be inactive. Faults may not present surfacial rupture since in many cases fault rupture since in many cases fault rupture does not reach the earth's surface.

The rupture surface of a fault, although usually irregular can be approximately presented as a plane. On this plane the focus or hypocenter of the event presents the point where the rupture started during an earthquake. The projection of the hypocenter on the earth's surface is called epicenter. Furthermore, the intersection of the fault plane with the horizontal plane is called fault trace or fault line. The fault plane orientation is presented by its strike and its dip. The dip angle is formed between the fault plane and the horizontal plane. If the fault plane is not vertical we can discriminate between two crustal areas. The area under the fault plane is defined as the hanging wall and the area under the fault plane as the footwall. Usually, the area over the hanging wall is mostly affected the earthquake induced ground motion. The azimuth of the strike is used in order to define the orientation with respect to due north. The forward slope of the fault is described by the dip angle, between the fault and the horizontal plane, vertical to the strike.

The type of the fault movement is presented by the fault slip and its direction. The rake of the fault is the slip vector direction of the hanging wall block on the fault plane, measured counterclockwise from the trace vector. Other measures of the fault movement, associated with the fault slip, are the following: - net slip, the total slip of the fault – dip slip and strike slip, the dip and strike parallel slip components, the vertical throw is the vertical component of the net slip and horizontal throw the total horizontal component of the net slip – heave, stratigraphic heave, the apparent component of the net slip.

Fault movement that occurs primarily in the dip direction is referred to as dip-slip movement. We can discriminate two fault cases of dip slip movement. Normal faults occur when the horizontal component of the dip slip is extensional and the hanging wall of the fault moves downwards relative to the footwall. Reverse faults characterize the opposite case when the horizontal component of the dip slip is compressional and the hanging wall moves upwards relative to the footwall. Fault movement occurring parallel to the fault strike is called strike slip movement. Strike slip faults are almost vertical and are characterized by a sideways movement of the fault. If an observer standing on one side of the fault perceives a rightward movement of the opposite side the fault is characterized as right lateral strike slip fault. The opposite case characterizes a left lateral slip fault. In most cases the real fault movement is oblique combining both dip slip and strike slip motion components. An oblique reverse fault is usually called obverse.

As relative movement in the earth’s crust occurs, elastic strain energy is stored and shear stresses increase in the materials near the fault plane. There is a build-up of elastic strain. When the shear stress reaches the shear strength of the rock along the fault the rock fails and the accumulated strain energy is released. If the rock is strong and brittle the failure is rapid. The rupture of the rock causes the drop of the shear stress and the relevant slip of the fault. The stored energy is released explosively partly in the form of heat and partly in the form of seismic waves that are felt as an earthquake. The theory of elastic rebound describes the process of the successive build-up and release of strain energy. In the elastic rebound theory, after the earthquake, the rock will be displaced with a displacement close to the build-up of elastic deformation accumulated during the previous to the event years. Keywords related to the elastic rebound theory are the following:

  - Dynamic and static stress drop. The static stress drop $\Delta\sigma$ represents the difference between the initial and final stress across the fault before and after an earthquake, and is related to the slip of the fault. In between the difference with the initial stress may achieve larger values and the we are talking about the dynamic stress drop.
  - The rise time or slip duration measures how long each point on the fault moves during the rupture process and must not be confused with the rupture duration. The rise time is related to the slip velocity or slip rate function. A usual value of the slip rate is 50-150 cm/sec.

    Rupture duration. The rupture duration characterizes the total time for the earthquake rupture process to complete, starting from the hypocenter and lasting until the last point on the rupture plane stops sliding. Rupture duration depends on the rupture velocity and scales with the source dimension of the earthquake.
- Rupture velocity. Earthquake ruptures, modeled as propagating cracks or slip pulses, expand over the fault plane at rupture velocities about 1.0 to 3.5 km/sec, similar to the wave velocities produced by the rupture.

Slip distribution along the fault. The uniformity that has up to now characterized the presentation of the source mechanisms regards an ideal case. Faults are not uniform, either geometrically or in terms of material properties. Both strong and weak zones can exist over the surface of the fault. The strongest zones referred as asperities are particularly important. The asperity model of fault rupture assumes that the shear stresses prior to an earthquake are not uniform across the fault because of stress release in the weaker zones by creep or foreshocks. Release of the remaining stresses held by the asperities produces the main earthquake that leaves the rupture surface in a state of uniform stress. The engineering significance of asperities lies in their influence on ground shaking close to the fault. A site located close to one of these strong zones may experience stronger shaking than a site equally close to the fault but further from a strong zone. At larger distances from the fault the effects of fault non-uniformity decrease. Unfortunately, methods for locating asperities prior to the rupture have not yet been developed. Since, at larger distances, the effects of non-uniformity decrease, the characteristics of a uniform fault rupture model are used in order to develop a useful measure for the size of an earthquake. The seismic moment of an earthquake is given by: Mo=GxAxD. The moment magnitude is a function of the seismic moment as follows Mw=2/3logMo-10.7.

The possibility of obtaining an objective, quantitative measure of the size of an earthquake came about with the development of modern instrumentation for measuring ground motion during earthquakes. Most measurements of earthquake magnitude are instrumental, based on some measured characteristic of ground motion due to seismic waves.

As already referred, during an earthquake event different types of seismic waves are produced: body waves and surface waves. Body waves, travelling through the interior of the earth, are of two types, p-waves and S-waves. P-waves are known as primary, compressional or longitudinal waves and involve successive compression and rarefaction of the materials through which they pass. P-waves travel through solids and fluids. S-waves are known as secondary, shear or transverse waves causing shearing deformations as they travel through a material. The motion of an individual particle is perpendicular to the direction of the wave travel. Fluids cannot sustain S-waves. S-waves are divided is SV – vertical plane movement – and SH – horizontal plane movement.

Surface waves result from the interaction between body waves and the surface of the earth’s crust. Surface waves are more prominent at distances further from the source of an earthquake. The most important surface waves are Rayleigh and Love waves. Rayleigh waves are produced from the interaction o P and SV waves and present both vertical and horizontal motion. Love waves are produced from the interaction of SH waves with a soft surfacial layer.

According to the measurement of different wave types there exist different magnitude scales. Richter defined what is known as the local magnitude given by the logarithm of the maximum trace amplitude recorded at a Wood-Anderson seismometer located at a 100 km from the epicenter of an earthquake. The Richter local magnitude is the best known magnitude scale but is not always appropriate for the description of earthquake size. The Richter local magnitude does not distinguish between different types of waves. The surface wave magnitude is a worldwide magnitude scale based on the amplitude of Rayleigh waves with a period of 20 sec. More specifically, the surface wave magnitude is based on the maximum ground displacement for shallow (less than 70 km) focal depth, distant (further than 100 km) moderate to large events. For deep focus earthquakes, the body wave magnitude, based on the p-wave amplitude at about 1 sec is established. It is important to realize that the previously defined magnitude scales are empirical quantities based on various instrumental measurements of ground shaking characteristics. As the total amount of energy released during an earthquake increases, the ground motion characteristics do not necessarily increase at the same rate. For strong earthquakes, the ground shaking measured characteristics become less sensitive to the size of the earthquake than for smaller earthquakes, a phenomenon called saturation. The body wave and Richter magnitudes saturate at magnitudes 6 to 7 and the surface magnitude at about an 8 magnitude. To describe the size of an earthquake quite large, a magnitude scale that does not saturate and does not depend on ground shaking levels is needed. Such a measure is given by the moment magnitude based on the seismic moment of an earthquake. Moment magnitude is accordingly based on the direct measure of factors that produce the rupture along the fault. The rupture characteristics of an earthquake, such as fault rupture length, rupture area and fault displacement scale logarithmically with the moment magnitude.