# CONSIDERATIONS ON SEISMIC DESIGNS FOR INDUSTRIAL PLANTS

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Seismic designs are very complicated and important design factors which must be treated with caution and care.

A "Seismic" event is related to an earthquake or earthquakes or other vibrations of the earth and its crust. An "earthquake" is a convulsion of the earth's crust due to release of accumulated stress as results of faults in strata or volcanic action. The resulting waves of vibration within the earth create time variable ground motions on the surface which, in turn, induce movements within buildings. "Seismicity" is the frequency of earthquakes per unit area in a region. The previous definitions should give us an idea that , due to the conformation of our planet and its geological history, the seismic areas, even those with different values of seismicity, are more common than the non-seismic one. An earthquake is always an uncertain phenomena. Nowadays Seismologists within Earthquake Hazards Reduction Programs in many different countries certainly have more technology than in the past in forecasting and now it is possible, to some extent, to predict possible location, magnitude, exposure factor and other characteristics but always within a degree of approximation due to the stochastic nature of the available investigation and data processing methods.

It is important to get as much reliable information as possible at the early stages of a project about the seismic peculiarities of the concerned area. In other words we need to get information about frequency, magnitude, recurrence period of the events associated with their magnitude (low, average, catastrophic), duration of the ground motion, geology of the site. All these factor affect the plant design. In fact, during an earthquake each point of a structure has movements in three directions: horizontal and vertical. The first two identify the undulation, the third one is the vertical component. Therefore the building and the plant will endure dynamic oscillations in accordance with its physical and design characteristics, and then time variable stresses.

A detailed preliminary investigation about geological and seismic peculiarities of a particular region, or better of a particular site (micro-zonation), within a certain country and then a good seismic design are fundamental. Doing so, we can tune the physical characteristics of the plant properly to the seismic peculiarities of the region. The target for both investors and designers is then to limit both the life and property loss and assure the need of attempting to ensure continued plant operation or minimize the disruption immediately after a seismic event.

It could be interesting for the Investor at early stages to have the evaluation of the seismic risk of a certain region or site available in order to define, even if approximately, the most suitable choice for a site from the seismic point of view. Obviously the seismic risk is not the only factor to be considered during the investment decision making process but, surely, it is one of the most important.

The seismic risk is defined as the probability that the consequences of the effects of an earthquake on economical and social aspects exceed, during a certain lapse of time, a determined threshold. The seismic risk of an area is evaluated, in a determined lapse of time, by the following:

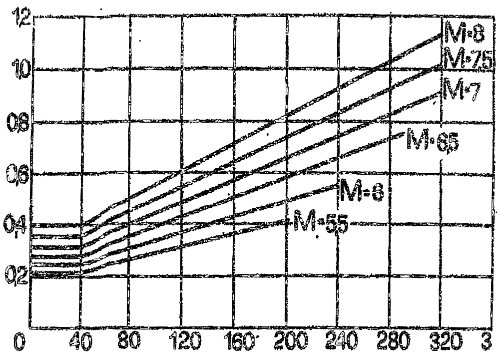
$$R=PxV$$

Where P is the seismic danger; V is seismic vulnerability. Seismic danger is defined as a probabilistic function of a seismic event, of its magnitude and recurrence period. Seismic vulnerability is the capability of a certain structure to absorb seismic actions and it is measured by the damages of the structure after an earthquake of a certain magnitude. Seismic danger, which can be evaluated by the use of a consolidated mathematical model, represents an approximate estimate of seismicity of an area. It is normally considered using two indicators: the peak horizontal ground acceleration, which is also used during the design and drives the construction characteristics of the structures in a seismic area, and macro seismic intensity which represents the damage caused by an earthquake not taking into consideration local effects due to the nature of the soil. Seismic vulnerability can be determined by simulation of the structural behaviour and feedback of a structure.

The risk is measured by an estimate of casualties, property loss, service loss. The associated estimated cost of the possible damage is useful to determine the advantages of risk reduction measures. The Investor should determine an accepted “Residual risk”, that is to say a forecast of the damage to be endured even after risk reduction measures are taken into account. Such measurers are almost proportional with the reduction of the residual risk.

The magnitude of a seismic phenomena is strictly linked to the nature of the region where the plant is or should be built but it depends on the lifetime of the plant itself, too. It is interesting to note that it is statistically determined that catastrophic earthquakes happen with minor time frequency. Furthermore recent studies and acceleration records during an earthquake supplied interesting information on the correlations between magnitude, distance of the observing point from the generating fault, maximum acceleration to be forecasted in the observing point and the fundamental period of the rocky layer (See Fig.1; Fig.2)

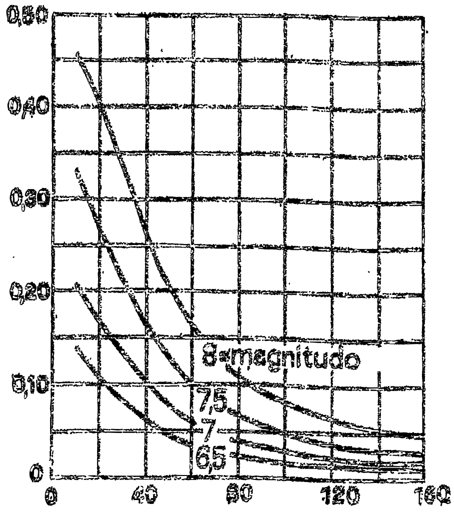
Harmonic Fundamental period (sec




Distance from the fault (Km)

Fig.1: Correlation between Magnitude (M), distance from the fault and the fundamental period

Max. Ground acceleration (g)




Distance from the fault (Km)

Fig.2: Correlation between Magnitude (M), distance from the fault and max. ground acceleration

Nowadays in most countries, even in the third world, it is rather common to find good and detailed information about the seismic history of the country as well as almost recent or updated codes which lead the designers during the seismic design. At the beginning, it is important to conduct a meticulous investigation campaign within the chosen country. Anyhow, the available country seismic zonation is sometimes almost recent and therefore difficult to determine a recurrence period of a catastrophic earthquake. Another case of particular interest is when the site or the region is close to the conventional border between two regions with different values of seismicity. In other words, the purpose is to determine the difference between a normal “operating” earthquake and an “exceptional” earthquake. It is therefore very helpful to conduct a micro-zonation of the site and then study building by building in detail by the most recent soil investigation technique, data processing and calculation methods. The definition of the nature of the foundation soil plays an important role in changing (amplifying or filtering) seismic waves and determines the mechanical soil characteristics, the damping factor or the amplifying factor. Seismic spectrum characterises the seismic area because its shape depends mainly on the contents of the harmonics of the ground acceleration function which, in turn, depends on the soil characteristics. It may happen, as an example, in a float plant, which covers a rather wide surface, that the different areas (Furnace, Float, Annealing lehr, warehouse, batch plant, utilities, etc.) , due to different soil characteristics along the process line, could have different seismic spectrums.

The design standards and regulations are to be considered the minimum requirements for the design and construction of structures but they are mainly for conventional civil building oriented. Their application to an industrial plant must be weighed up with care in order to find the proper analogies, bearing in mind either the targets or the value of allocated budget for the investment. Industrial plants are constituted with non-conventional buildings, which have a different behaviour to dynamic excitation compared to conventional buildings, and process line. It is possible to carry out a good seismic design for the buildings, whereas nobody could exactly predict, with the current state of knowledge so far available, which the transversal effects of an earthquake on the furnace and on the float are.

Furthermore particular plants such as: tanks, reservoirs, batch plant must be studied by the use of specific standards and by the use of dynamic analysis. Especially for the batch plant on a whole it is interesting to evaluate the dynamic behaviour of the structure with silos and belt conveyor bridges and then assess the risks.

The international seismic regulations are oriented to guarantee a building must resist, in addition to the loads imposed by normal use, to small earthquakes without damage (recurrence period of about ten years), medium earthquake without significant structural damage but with some damage and strong earthquakes with structural and non-structural damage but without collapse (recurrence period of about hundred years). This can be assured for structures with a certain ductility, such as steel structures and reinforced concrete structures, by making sure that the verification within the elastic field is satisfactory. This aspect will make the collapse and also the plastic deformation of the structure avoidable. If it is accepted by the Investor that the structures have a certain capability to the plastic adaptation as a consequence of horizontal forces during an exceptional strong earthquake, the collapse will be avoided and the designers can consider lower seismic forces than those considered by a dynamic analysis in the elastic field. Therefore the investment will be reduced but the damage could be higher in case that a strong earthquake occurs.

I would say that first of all early discussions between the Design team (designers and geologists) and the investor should explore important aspects such as, siting decisions, nature of the soil, seismic performance of the plant, acceptance and level of sustained damages in order to provide the designers with well defined requirements.

At an early stage Investor, designers and geologist must work shoulder to shoulder in order to reach the expected targets. There are some aspects (site, residual risk, classification factor, etc.) which must be defined by the Investor and some other aspects must be determined by the geologists (soil characteristics, seismic risk analysis, etc.). All this information will supply the designers the frame within which they can play their role. In other words the Investor should classify, from the Insurance point of view, the plant by dealing with an Insurance company during the decision making process, as well. Normally higher the risk classification category is higher is the insurance risk premium is to be paid. As already said, the industrial plant is composed by non-conventional buildings, therefore the risk classifications as defined in the Standards, are not immediately applicable. Considerations on their use, desired lifetime, cost, residual risks, damages which can be sustained, production disruption, etc. must be considered by the Investor. The designers with the precious assistance of a good geologist team should fulfil the expected targets. This basic decisional phase will significantly affect the design. If a too high security margin on the basic data is taken at the beginning, this will have a decisive impact on the final cost of the construction. Therefore a very cautious analysis is highly recommended at the early stage of the project.

In conclusion a good seismic design will be in favour of the total cost of the investment and their depreciation. Some key points have to be considered to reach the target. One of those is the assimilation of the idea to invest in the project engineering and its co-ordination more than for a plant in a non-seismic area. This plus will minimize the total final cost of the investment, even if this is higher than that for the same plant in a non-seismic area and assure a higher safety margin for the plant lifetime. Nowadays the availability of modern structural calculation method could tempt the Investors in studying the behaviour of the process line during an earthquake and then the risk reduction measures. This is another key-point to be considered.

Again, another important factor is the selection of the design partners: either the design company or the geologists. The Design company should be capable to design both the reinforced concrete and steel structures. It must be equipped with modern calculation software able to simulate 3D dynamic behaviour. Geologists must be first-class professionals, equipped with up-to-date systems for soil investigation and data processing. If not, it is recommended to search for consultancies, for example, from local Universities which normally have the proper technologies, knowledge, suitable calculation tools.

I have tried to highlight in this article the exploration of some qualitative aspects to be considered also in preliminary design or during the investment decision making process. Therefore, I have taken advantage of my experiences gained in design and construction of several glass projects during these years of business in the field.

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