SEISMOTECTONIC IN EARTHQUAKE ENGINEERING

Milan Arsovski[1)]

The high rate development of mankind and urbanization during the past decade, resulted in increasing concentration of population followed by intensive progress of industry and road systems which required development of new scientific disciplines inavitable for both further evolution of mankind and protection against natural disasters.

The earthquake is a natural hazard which has been receiving increasing attention recently. Earthquakes are associated with certain regions in the world causing in them losses and damages beyond the economic capabilities of the small and underdeveloped countries and require solidarity of the whole world. The earthquakes which occurred in our country (Skopje, 1963 and the Monte Negro coastal area, 1979) is another proof of the fact. These and numerous other earthquakes occuring each year in various places on the earth cause permanently, in addition to human losses, severe losses of properties mostly to civil engineering structures and industrial facilities, which represent the basis of mankind.

Modern man, in geographically various and distant areas, mostly those threathened by the disastrous effect of earthquakes, makes tremendous efforts to investigate these phenomena, to discover their secret forces and by studying the parametres of their action to define measures for mitigation and overcoming their effect. Beside other scientific disciplines, seismotectonics is considered as an interdisciplinary geological science. It is related to the geological disciplines since applying mainly geological methods it is dealing with tectonic movements and deformations of the earth crust, which in turnes condition the seismicity of an area.

The major subject of seismotectonics is definition of the earthquake generation conditions which are genetically associated with recent tectonic development of the existing earth crust structures. Studying the activity of resent structures in certain seismogene zones, seismotectonics, as a geological discipline, should define the place of earthquake generation in a way that by investigating the conditions of their generation the geological criteria conditioning the intensity of the earthquake may also be defined.

Special emphasis should be add to the fact that seismological data for some regions are very insuficient or not available at all, though evidences indicating seismotectonic activity of the region exist. This is related to the fact that instrumental seismological data have been available not before recently (for the territory of Yugoslavia these data exist only for XX century).

So, investigating processes ongoing during the past geological age, seismotectonic represents the only source of information required for definition of seismicity, identification of the epicentres of future earthquakes and estimation of their expected magnitudes.

It means that the main objective of seismotectonics is to define the PLACE and the POTENTIAL of the seismogene sources which constitutes

1) Professor, Institute of Earthquake Engineering and Engineering Seismology (IZIIS), University "Kiril and Metodij", Skopje

its importance as a science. Considering the fact that all the processes take place on the ground surface, i.e. in the earth crust, seismotectonics plays an important role in earthquake engineering, especially for the regions of potential seismic hazards. It reffers both to solving regional problems during elaboration of physical development plans, and provides seismic stability of structures of capital investment in industry, traffic, public and residential facilities and so on.

SEISMOTECTONICS IN REGIONAL PHYSICAL PLANNING

In solving problems of regional physical planning for seismically active regions, seismotectonics, in addition to other important factors, being a necessary background for regional planning, takes a special place through the elaboration of seismic zoning maps. It has been recognized that the seismic zoning map represents synthesis of seismological and geological parametres having significant role in definition of seismogene source characteristics, their genesis, location and intensity. These are primarily tectonic parametres, i.e. structural forms created during tectonic activities, which condition the seismicity of the area. By definition of the location and the energy of the seismogene sources and their possible mechanism from geological aspects, as well as considering the irregularity of the tectonic movements, the seismic zoning map provides the parametres necessary for town planning by indicating the seismically "dangerous" and "nondangerous" zones. Seismically "dangerous" zones, where rather high earthquake effects are likely to be expected, require special investigation and definition for urban planning purposes. The land use pattern in them should ensure minimum negative consequence and damage in case of an earthquake so that it is significant to undertake all the necessary measures for protection against and decrease of seismic forces. Dangerous zones, where strong earthquakes could be expected, are marked on the seismic zoning maps, which on the other hand are to be taken account of in elaboration of Construction codes of countries in earthquake prone regions.

On the other hand, by investigation of seismogene sources, their locations, the conditions of their genesis and their energy, as presented in the seismic zoning map, it is obtained basic data, to be applied in planning, i.e. in the future processes of development of the region (mostly development of road facilities, industry, and elaboration of detailed microzoning maps, which in turns are the essence for elaboration of detailed town plans for almost all larger settlements in seismic regions.

Seismotectonics, through its methods for definition of the location of seismogene sources, makes possible to have insight of their distribution which is important for the further steps in the planning process, i.e. in earthquake engineering.

2. SEISMOTECTONICS IN EARTHQUAKE ENGINEERING FOR CONSTRUCTION OF CAPITAL INVESTMENT STRUCTURES

Seismotectonics is of special importance for design of engineering structures of capital investment, as divided into 1. road facilities, 2.hydrotechnical and other energy producing facilities and industrial facilities and 3. with special attention to solving problems concerned with nuclear power plants.

2.1. Road facilities. For design of regional roads, highways and railways, which could run across rather complex relief conditions requiring construction of costly structures like bridges, tunnels and loops, seismic parametres should be defined as they are probably to be of considerable

importance for their future stability. For such regions seismotectonics should define the earthquake bearing structures, and in the case when a capable fault can not be avoided and passes near-by or under the structures adequate solutions should be applied in order to protect them. For illustration the collapse of one of the bridges on the highway during the San Fernandó earthquake of February 9, 1971 should be mentioned.

2.2. Hydrotechnical structures. Seismotectonics as correlated to earthquake engineering is very important in design of some hydrotechnical structures, such as dams and reservoirs, which require high level stability against earthquakes, i.e. no deformations which could cause catastrophic damages are allowed.

Many dams, with heights from 100 to 300 m, which are man made bars for reservoirs accumulating tens of milions to several billion cubic metres of water are known to be constructed and will be constructed within seismic areas. Disregarding the fluid effect upon the seismic regime (it usually increases) I am of opinion that the seismotectonic characteristics of the areas suggested for dam construction as well as the tectonic structures and their irregularity caused by diverse tectonic processes should be studied even during the stage of preliminary design. It is very important to determine whether it is within a unit block, which is uplifting or subsiding or is experiencing some other processes, which should require previous complex geological, geomorphological and neotectonic investigations. It is necessary to distinguish and classify any disjunctive dislocations, with detailed investigation of the active seismogene faults, tectonic knots, flextures and so on, paying special attention to their stretching direction with respect to the hydrotechnical structure which is planned to be constructed. Thus, in the case of a capable fault within the accumulation basin area, with longitudinal stretching direction associated with rather steep slopes and adequate geological structure (circumstances) and favourable tectonic conditions, an earthquake could cause deformations to the relief (land slides and rockfalls of higher scale) which could further induce severe damage consequences.

If the reservoir is transversally crossed by a capable fault conditoning the local seismicity, an earthquake could cause not only undesirable consequences due to the seismic effect in the reservoir, but also opening of the fault which could turn into a canal through which large quantities of water could empty into uncontrolable direction. This could cause direct damage considered as loss of water, but it could also cause downstream floods.

In selection of the most appropriate type of dams and their suitability earhquake engineering should also consider the seismotectonic parametres necessary for definition of stability of such structures during the stage of investigation of the local engineering and geological conditions. Detailed seismological characteristics of the construction site should be studied and the fault dislocations and their activities should be distinguished and defined since they might have significant influence upon dam stability during an earthquake.

For definition of the local seismic activity for the considered hydrotechnical structures previous investigations of the seismic activity for definition of the seismic regime distinguishing of the seismogene structures and their monitoring (investigation both during reservoir construction and accumulation and serviceability period) are necessary. Geological parametres

Defining seismotectonic characteristics of such areas should be accurate with fair evaluation of the seismic effects probable to have been due to the recent activity of capable faults. The criteria for definition of these parametres should be very strict particularly for construction of high arch concrete dams, which under seismic effect could suffer deformations capable of inducing devastating consequences.

Being of particular importance in earthquake engineering, the definition of regional and local seismo-tectonic conditions are also necessary for construction of other costly structures of capital investment such as electric power plants, oil rafineries and other industrial and civil engineering structures.

2.3. Nuclear power plants. Earthquake engineering criteria applied for construction of nuclear power plants are particularly high and important since they refer to structures which are very costly and require high rate stability and safety during operation. The local and regional seismotectonic characteristics are of considerable importance for definition of the design parametres which should assure seismic stability and safety during operation. If the earthquake engineering requirements from the viewpoint of seismotectonic were not strictly stated for structures previously constructed, and various solutions are looked for in selection of a suitable nuclear power plant site there are criteria which have been already defined. Seismotectonic parametres are well defined though not quite comprehensive. In support to this statement is the heterogenity of the geological structure related to the seismotectonic processes inducing considerable differences in the characteristics of each site.

According to the existing US Regulations and those published by the Atomic Energy Commission in Vienna (4,5), regional seismotectonic investigations should define the strong earthquakes occuring at a distance of 200 miles (more than 300 km) which is often beyond the border lines of a country. This requires top readiness and capability of the professionals dealing with this problem.

The stated Regulations set forth some requirements for the earthquake engineering which include definition of all the parameters of the existing tectonic structures and their seismic activity. It is also emphasized that, in addition to their morphological and genetical characteristics, faults and dislocations should be classified also according to their activity observed during Quuarternary, i.e. in the past 500.000 years. Applying the radioactive method with "C 14" isotop, in the case of lack of other data the fault activity during the past 35000 years should be defined. (These methods offered positive results in investigation of the San Andreas and some other faults).

Seismotectonic investigations in nuclear power plant siting should define all the existing elements. First the number and distribution of seismic evidences on the ground surface within the site should be determined. It is well known that structures of this type should not be constructed on an active fault, and according to the range of their importance strict distance rates for the nearest approach to the site should be followed.

According to the US Rules and Regulations the minimum distance from site is defined in the following table:

Distance from the site (miles)	minimum length(miles)
0 to 20	1
Greater than 20 to 50	5
Greater than 50 to 100	10
Greater than 100 to 150	20
Greater than 150 to 200	40

In order to demonstrate seismic activity associated with the considered faults in definition of the capable faults it is necessary to investigate and synthesize all the parametres of the geological structure of the site, its geological evolution and the course of the neotectonic and the recent processes. This requires that geological data necessary for definition of the seismotectonic activity be exact, which in turns requires complex investigation of both the wider area of the future site and the site itself.

In conclusion to what have been presented, it can be stated that though being a new scientific discipline, seismotectonic combined with other sciences is responsible for provision of several important parametres required for the earthquake engineering practice.

REFERENCES

1. Bolt, B.A., Horn, W.L., Macdonald, G.A., Scott, R.F., 1977, Geological Hazard (Earthquakes, Tsunamis, Volcanoes, Avalanches, Landslides, Floods) Seminar, Verlag. Berlin Heidelberg New York.
2. Bonila, M.G., 1967, Historic Surface Faulting in Continental United States and Adjacent Parts of Mexico, A Factor in Nuclear Facility Siting and Design.
3. Bogge, H.l., 1972, Method for Estimating Design Earthquake Rock Motion, Engineering and Research Center, Denver, Colorado.
4. Earthquake Guidelines for Reactor Siting. International Atomic Energy Agency, Technical Reports, series No. 139, Viena, 1972
5. Seismic and Geological Siting Criteria. Rules and Regulations. Federal Register. Vol. 38, 1973
6. Proceedings of the Seminar on Seismic Zoning Maps. Vol. I and II. UNDP-UNESCO Survey of the Seismicity of the Balkan Region. UNESCO, Skopje, 1976.