PHYSICAL PLANNING IN SEISMIC REGIONS

Tiberije Kirijas

Introduction

Large scale destruction caused by the effects of disastrous earthquakes in areas with high seismic activity indicates the necessity for undertaking corresponding protective measures for the purpose of reducing destruction to the lowest possible level. This is especially the case because of the possibility earthquakes can affect large urban areas. With the permanent development of urban areas and consequent construction of a large number of structures requiring significant expenditures (energy, transportation, industrial and other structures) responsible authorities more and more face the requirement to protect such large investments from the destructive effect of earthquakes as much as possible.

Earthquake destruction has provided the motivation for detailed investigations of earthquake effects upon buildings and civil engineering structures as well as infrastructure systems with the basic aim of undertaking corresponding protective measures, depending on the economic and technical power of the country involved. The implementation of technical regulations for design and construction in seismic areas is the basic protective measure which provides the required resistance of the structures against earthquakes.

The implementation of protective measures against destructive earthquake effects upon structures is much more effective than mitigation of other direct or indirect consequences of earthquakes. The present level of knowledge and techniques enables effective implementation of protective measures against the destructive effect of earthquakes upon structures through the methodology of physical planning and urban design in earthquake prone areas. The physical and urban planning for seismic areas is a young discipline. It has evolved for the most part, since the disastrous earthquake of Skopje in 1963, i.e. with the development of the General Urban Plan of Skopje.

The protective measures against disastrous earthquakes through physical planning and urban design in seismic areas are carried out, mainly, through the following basic methodological elements:

- determination of land-use zones for location of urban areas (towns, industrial complexes and other settlements),

- deconcentration of production and other activities,
- determination of land-use zones within urban areas, and
- decreasing the density of construction in settled areas.

In implementing these methodological elements of physical planning and urban design in seismic areas the following results must be considered:

- by selection of construction sites for settlements or important structures in areas with lower seismic activity the damage due to disastrous earthquakes will be diminished;
- concentration of productive activities (industry and other) in densely settled areas through physical planning will result in greater damage in case of a disastrous earthquake, and vice versa;
- the land-use patterns in seismic urban areas can greatly contribute to diminishing or increasing levels of damage;
- damage will be much less when the density of development in larger urban areas is lower and vice versa.

The following maps form the basis for effective implementation of the protective measures through planning and urban design in seismic areas:

- map of seismic zoning of the region with a number of appendices
- map of seismic microzoning of the urban area.

Regional Physical Planning in Seismic Areas

Regional physical planning in seismic areas is performed in the same way as for non-seismic areas, with the difference that the map of seismic zoning of the region with appendices is also taken into consideration as basic information. Regional physical planning in seismic areas is not based exclusively on seismological engineering aspects, but these factors are considered together with other basic aspects of regional planning. Including the map of seismic zoning of a region in physical planning considerations can assuredly decrease seismic risk, i.e. mitigate the effect of a disastrous earthquake upon human lives and material goods.

On the basis of detailed regional seismological, seismotectonic, engineering seismological and other investigations a seismic zoning map of a region can be developed. Such a map defines the general seismic risk of a region. It shows the distribution of regions of different seismic intensity from VI to X degrees according to MCS scale (Mercalli-Cancani-Sieberg). The seismic areas marked with seismic intensity of VIII and IX degrees are characterized as of high seismic intensity.

The seismic risk shown on the seismic zoning map is determined by the following elements:

- seismogene zones with maximal expected seismic intensity, with their characteristics and parameters, are defined:

- fault zones and faults, as well as their relation to seismic activity are delineated:

- seismic sensitivity is established based on different geologic media in the region.

Basic maps appended to the seismic zoning map are the following:

- map of focal zones and approximate return periods of earthquakes (100, 200, 500 and more years)

- seismotectonic map, and

- seismological-engineering map.

Mitigation of seismic risk through physical planning is achieved by application of the following basic elements:

- establishing land-use areas within a region for location of urban, industrial and other settlements;

- location and expansion of infrastructure networks, and

- deconcentration of production facilities from the larger centers of the region.

These basic elements for the mitigation of seismic risk are implemented through the development of national and regional physical plans, as follows:

- In the selection of construction sites for urban, outlying, industrial and other settlements, which are considered in regional physical planning, the seismic zoning map with all appendices are analyzed in detail for the purpose of mitigating seismic risk as much as possible from the very first step of selecting locations for these settlements. The location selected should be those with smaller seismic intensity, with longer return periods without active seismic faults, and within geological media which have weak seismic sensitivity.

- All regional life-line systems (railroads, motorways, gas pipelines, oil pipelines, etc.) represent very large investments and constitute structures of vital importance. Protective measures against earthquakes are implemented through regional physical planning in seismic areas, primarily through the following elements:

  - location of life-line structures and

  - location of structures which are functionally related to life-line structures (bridges, viaducts, reservoirs, power stations, etc.)

In locating life-line systems in the context of physical planning, the seismic zoning map with all appendices should be considered along with other factors. It is of great importance to avoid regions of high seismicity, unstable terrain and potential land-slide areas. Locations should be selected far from potentially active seismic zones, and especially should not cross such zones. The procedure for selection of location for the life-line systems and related structures (bridges, viaducts, reservoirs, etc.) is the same as for settlements.

- Regional physical planning also projects the general patterns of future development for urban and other settled areas in the region. Usually, in larger towns, and especially in the centers of some regions, major concentrations of different activities are planned, such as economic (industry), public, cultural, health, education and other. In the case of strong earthquakes in such regions with high concentration of activities the vulnerability is much greater. This can have disastrous effects, not only on the economic activities in the region, but in many cases on other regions far beyond its limits. A well-considered dispersion of activities over the region provides for the safety of some economic and other activities which can continue even after a seismic event. Such considerations in regional physical planning in seismic areas are of great importance since they provide greater resiliency of the economic system to the effects of disastrous earthquakes.

Urban Planning and Designing in Seismic Areas

One of the basic elements in urban planning and design in seismic areas is the seismic urban microzoning map with its appendices. This map is developed on the basis of previously performed detailed investigations of the urban area including seismological, seismotectonic, seismological-engineering, geophysical, geological-engineering, geomechanical, hydrological and other studies.

The seismic microzoning map of an urban area should show zones of maximal expected seismic intensity, and even sub-zones. The map should also show all characteristics from performed seismotectonic, geological, geomechanical, hydrological and other investigations, i.e. the characteristic elements of the soil, which show the suitability of the terrain for construction. For this purpose the following maps are presented as appendices to the seismic microzoning map: seismotectonic, geological, goemechanical and hydrological maps as well as the map with predominant periods of the ground. This set of maps gives a clear picture of:

- the detailed distribution of seismic risk in terms of each zone and sub-zone within the urban area, and

- the suitability of the terrain for construction in different zones and sub-zones of the urban area, i.e. the bearing capacity of the ground, the ground water level, flood areas, unstable terrain, possibility of land-slides, seismically active faults, etc.

The results obtained as a result of the investigations mentioned above show the influence of the local soil conditions upon the seismic intensity and the character of the earthquake effect.

The seismic microzoning map of an urban area is used as the basis for urban planning and design for the purpose of mitigating the seismic risk from the effect of disastrous earthquakes. In the development of the physical concept of the urban plan, in addition to other considerations, the following elements are also taken as basic:

- The seismic microzoning map of the urban area shows clearly the possibilities for rational utilization of the terrain for developing the physical concept of the urban plan (zonal plan). The zones with most favorable conditions, i.e. where lowest maximal seismic intensities are expected are clearly defined. Usually, these zones are preferred for construction.

  Such seismically favorable terrains should be used as construction sites of the most important basic urban activities as well as for future urban development (center, important industrial structures, housing, hospitals, university campuses, etc.). However, the dispersion of industry into several industrial zones within the urban area of larger towns should also be considered, so that disastrous earthquakes will not have the same effect in all industrial zones.

  Terrain unfavorable for construction should be allocated in the physical concept of the urban plan, if possible, to other activities (light industry, services, warehouses, etc.).

- Terrain with unfavorable soil conditions should be considered in a similar manner as seismically unfavorable terrain, unstable terrain with most unfavorable ground characteristics, unstable terrain with potential for land-slides, terrain with high liquefication potential and flooded terrains. Such terrain in the concept of the urban plan should be used for green areas or open spaces.

It is recommended there be larger green areas and open spaces than provided by the usual urban regulations. In case of disastrous earthquakes the green areas may have a variety of useful advantages.

- Terrain with high ground water level and periodically flooded areas, if possible, should be first improved by application of various hydrotechnical measures and then be included in the general concept of the urban plan. Otherwise such terrain is seismically unfavorable.

- The position of faults and fault zones can be observed on the seismotectonic map. In designing the land-use patterns in the physical concept of the urban plan seismically active fault zones should be considered.

  Important facilities should be located distant from seismically active fault zones.

In planning and designing all structures and various types of infrastructure in large urban areas with high seismic activity special attention should be given to protective measures so that they can remain effective in case of catastrophic earthquakes. Basic recommendations concerning planning and design of infrastructure in urban areas are as follows:

- The urban plan should avoid organization of a single main traffic center, since that can result in complete disruption of normal traffic after a disastrous earthquake.
- Interregional through traffic should be accomodated by a system of roads which do not traverse the urban area but are easily connected with it.
- The complete water supply system, or at least large portions of it, of these settlements should give priority to the gravitation system if possible, since it does not require another energy source.
- The main water collectors, i.e. from the reservoir to these settlements should consist, if possible, of double pipes.
- The combined sewerage system collecting both waste and storm water is considerably more effective than other kinds (the pipes are placed deeper). This system should also consist of two pipes, if possible.
- In principle, gas systems should be avoided, if possible, since they can cause secondary damage by fire in large urban areas with high seismic activity. In case such systems are planned it is necessary to provide for automatic disconnection of the system in the event of a catastrophic earthquake, as well as for devices which will enable disconnecting damaged sectors from the system.

Preparation of a detailed urban plan often involves considerations of various aspects of structures and building complexes. In such cases in addition to other basic principles for urban design, the following measure for protection against the effect of disastrous earthquakes should also be taken into consideration:

- In principle, systems of structures should be separated from each other. If structures have some distance between them the possibility of damage due to battering each other is diminished. If structures are located at reasonable distances from each other the possibility of damage by buildings collapsing on each other is minimized.
- The detailed analysis of the causes of destruction and damage of a great number of structures due to the effect of catastrophic earthquakes has established that the shape of the base and its dimensions have considerable influence upon seismic stability. Thus, the outline of a building should be symmetric to the main orthogonal axis. It is best if buildings have square or rectangular shapes.

In case of structures with complex bases and structures where certain parts have different numbers of stories, they should be divided by seismic joints in such a way that the bases of the divided parts should have simple geometrical shapes.

Construction in rows should be, in principle, avoided. In case such construction is planned, such buildings should be separated by seismic partitions at selected intervals.

- Structures which vibrate with the same resonance as the soil are subjected to greater damage than those which have a different resonance. Because of this, when determining the number of stories of a building complex in the framework of urban plans, the map of predominant periods of the urban areas should be taken into consideration along with other factors. This map shows the distribution of zones with the same predominant periods. Thus, in areas with very small predominant periods, usually from 0.15 - 0.25 sec., it is recommended construction of low buildings be avoided, i.e. buildings of one to three stories. On terrain with small predominant periods low buildings can be constructed, as well as high ones.

The preceding discussion provides a very brief summary of considerations that should be taken into account when developing physical plans for seismic regions in order to mitigate the effects of disastrous earthquakes. It has not been possible in this short paper to elaborate the points presented. All problems discussed above have been presented in more detail in my lecture notes for the postgraduate course of studies in the field of earthquake engineering and engineering seismology organized by the Institute of Earthquake Engineering and Engineering Seismology at the University of Skopje.