# SEISMIC RISK - AN IMPORTANT PARAMETER FOR TOWN PLANNING IN SEISMIC REGIONS

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SUMMARY

In this paper are presented recommendations for application of the results obtained by seismic risk analysis for town planning in earthquake prone regions. These recommendations refer to several towns within the Montenegro coastal region in Yugoslavia, which were struck by the catastrophic April 15, 1979 earthquake, having a magnitude M = 7.2. For the needs of reconstruction and elaboration of the town plans for these towns extensive investigations have been carried out, including seismicity studies, seismic hazard and expected vulnerability assessment, and definition of the expected seismic risk level. Based on the obtained results recommendations have been elaborated, which should be considered as an attempt for directing towards assurance of adequate town planning solutions that would provide certain conditions for preventive protection agains future earthquakes.

## INTRODUCTION

The town planning, as one quite composite task, becomes even more complex when applied in seismic active areas. The particularity of town planning in seismic areas is in necessity to have determined the seismic conditions of the area and include them in the designing. This results in the conclusion that the basic aim of town planning in seismic areas is mitigation of the seismic risk by undertaking optimal measures of protection based on the principles of the earthquake engineering and engineering seismology. The application of all the principles which, through the town planning, would assure that the cpnditions for protection of earthquakes be recognised in complience with the other design principles as technical, economic, social, functional, esthetic and compositional, and others.

The elaboration of town plans for existing towns in seismic regions, with all the specific characteristics which are not based on the above mentioned principles is a special problem. They offer limited possibilities for more complex interventions, by which at least minimum conditions for preventive protection against future earthquakes can be provided.

On the basis of the results obtained by the seismic hazard assessment and the evaluation of the expected vulnerability and the seismic risk level as well as the microzoning of several towns within the Montenegro coastal area, and according to the recommendations for application of these investigation results in the new town plans, an attempt has been made in this paper to introduce a methodology for town planning in seismic areas, which, in this particular case

Considering the complex nature of the urbanuzation process in seismically active areas, the presented experience should be understood only as an essential step forward in providing adequate town planning solution in seismic conditions by undertaking all measures for mitigation of the seismic risk.

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For simpler and clearer presentation of the mentioned experience, it is connected with the specific aspect of town planning under seismic conditions and presented as such further in this paper.

## SEISMICITY OF THE REGION

The Montenegro Coastal area, which has been considered under this study, was strucj by a catastrophic earthquake on April 15, 1979. The earthquake intensity in the epicentral zone was I = IX MCS degress, or M = 7.2 Richter degrees. The earthquake caused demolition of more than 250 settelements, including all larger towns io the Montenegro coast: Ulcinj, Bar, Petrovac, Budva, Tivat, Kotor, Risan and Herceg Novi. All these towns are known by their cultural and historical monuments, concentrated mainly in their old town cores. The earthquake caused destruction of more than 750 cultural and historical monuments.

Due to the high seismic activity of this region (see Fig. 1) the reconstruction and the construction of new structures had to be based on all principles of the earthquake engineering and engineering seismology. Because of

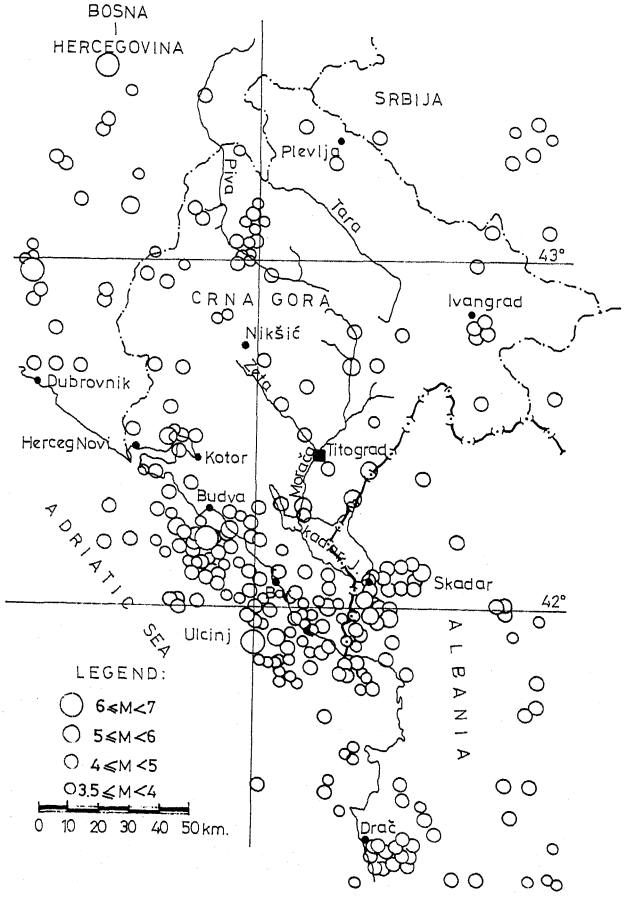


**Fig. 1. Epicentral map of the region**

this intensive geological, seismological, geophysical and engineering-geological investigations have been carried out to assess the seismicity and the seismic hazard level (Fig. 2), in addition to a large number of analytical studies and engineering analysis to determine the causes for failure and damage to structures to define the expected vulnerability and the acceptable seismic risk level.


**Fig. 2. Seismic hazard map — PGA distribution for 200 year return period**

The evaluated seismic risk level set some additional requirements in the reconstruction of the affected towns, particularly in the elaboration of the town plans to be used as basis for reconstruction and construction of new structures. The seismic conditions and the local seismic hazard level of some zones of the urbanized areas of these towns pointed to the need for rearrangement of the land use pattern in certain zones. However, the existing buildings and the presence of an already shaped urban unit with all specific points which are not always based on the earthquake engineering principles, make considerably more difficult the rearrangement of the land use pattern. Due to this in most cases it was necessary to bring compromising solutions with respect to the basic urban concept and the existing seismic conditions.

## Seismic Bases for Directing the Spatial Distribution

For establishing acceptable concept for spatial distribution of settlements and inhabitants, of special importance are investigations of the natural

factors and the analysis of the existing (made) conditions. In seismic regions the seismic activity is one of the most important parameters for organizing, arrangement and use of the land. Depending on the level of investigation of the seismicity of a region, an evaluation of the expected effects from earthquakes can be made for the need of undertaking corresponding protective measures even in the phase of urbanization of the region.

Therefore, for an efficient application of the protection measures through town planning, it is necessary that, in addition to other data, seismological maps are provided in terms of:

- Seismic hazard, i.e. seismic zoning maps of the considered region with all enclosures
- Seismic microzoning maps of urban units - towns, with all enclosures
- Technical and economic seismic risk analysis of the considered region or urban unit.

The problems related to the protection measures against catastrophic earthquakes could be solved through the town planning process only if they are considered as an integral part of the complex criteria of technical,economic, functional and esthetic, and compositional nature. It should be mentioned here that the effect of undertaking preventive and protection measures, in complience with the economical and technical development level of a country, in the stage of planning and design is higher and more rational, compared to all those which would be undertaken in a latter stage for the purpose of elimination of the earthquake consequences.

The permanent development of urban units and the construction of structures of vital importance in seismic regions confirms the needs for these important investments to be protected against natural disasters, including earthquakes and their most severe destructive effect.

By development of social goods, at present and in future, it should be expected that the catastrophic earthquake damage will proportionally follow the social goods development level.

All building structures, constructed in a town within a seismic area, are subjected to the devastating effect of the earthquake. The earthquakes, as natural forces, have a short time action and can destroy vital structures in populated settlements. The shock effect is very strong and it desturbes completely the normal life of each settlement.

The earthquake effect of building structures depends, as well, upon:

- Location of the populated area (town)
- Concentration and density of construction
- Land use pattern
- Application of technical regulations
- Undertaken preventive and protection measures.

The earthquake protection measures in town planning and construction are requirements and obligation of the society. The contemporary science and technique level enables an efficient application of the protection measures using an adequate methodology of town planning in seismic regions and by strict application of technical regulations for design and construction in seismic regions.

## SEISMIC MICROZONING

One of the essential basis, beside a number of others, in urban planning in seismic areas, is the seismic microzoning map with all its enclosures. This map is to be elaborated on the base of detailed seismological, seismotectonic, geophysical, engineering-geological, hydrological, engineering-seismological and other investigations. The seismic microzoning map is composed of separate zones, and eventually of sub-zones, of maximally expected seismic intensity and characteristic elements of the above mentioned investigations, which show the influence of the local geological conditions upon the seismic intensity and the character of the earthquake effect. All these elements, shown on the seismic microzoning map, , show the suitability of different town zones for construction. Fig. 3 shows a part of the seismic microzoning map of a town in the Montenegro coastal area. Due to certain limitation this part of the map does not include all elements that are usually presented in such maps. In Fig.3 are presented only few date on the intensity, the peak acceleration and the seismic coeficient in some selected zones.

Since the seismic microzoning map should be considered as basis for the land use of certain town areas, as well as for directing of the structural distribution, it is necessary to take into account, as well, the following recommendations:

- During the town planning and design process efforts should be made to comply, as far as possible, to the land use pattern, i.e. the distribution of some structures and other town elements, with the expected seismic excitation in separate zones. In this respect efforts should be made in order to have the structures or the urban elements, which are sensitive to seismic excitation, distributed in zones with lower seismic excitation values.
- However, considering the fact that besides the seismic conditions there are many other elements influencing the land use pattern and distribution and that in many cases they will be governing, corresponding differences in the investment costs between the structures located in zones with different seismic effects should be expected.
- Efforts should be made to comply, as far as possible, the construction and population density with the expected seismic effects of some zones. Tht is, construction and population density should be decreased with the increase of those effects.

Here should be pointed out the problem of the existing structures, or urban units, with their specific character, which have not been constructed in complience with the mentioned recommendations. Therefore, it is recommended that during construction and urbanization of the existing parts of the town these recommendations be applied as far as possible. It means that, in some cases, compromising solution will have to be applied, in sense of the basic town planning concept and the seismic conditions.

## SEISMIC RISK ASPECTS

Structures and other urban elements, excited by earthquakes, suffer different damage, i.e. they have different vulnerability level. It means that the vulnerability of structures and other urban elements depends upon both their dynamic properties and the excitation level. However, since the excitation level depends on the return period, while the probabilityi.e. the danger of

the damagible effect of the excitation at a certain time period depends on the serviceability period of the structure, or the urban element, it means that the velnerability as well is time dependent.Furthermore, since the vulnerability level is different, while the occurence of an excitation is probabilistic, it is required to make a selection of acceptable vulnerability degree i.e.to consider the probable occurence of an excitation.The results of the simultaneous and summarized consideration of the mentioned elements,i.e. the inter-relations between the earthquake occurence and its effect on the overall human activity, is expressed by a probabilistic approach as a seismic risk. The seismic risk level is the acceptable vulnerability of the structure or an urban element, for a corresponding return period and level of probable excitation.

Having in mind the described seismic risk concept in town planning and designing, the following should be considered:

- Within the scope of elaboration of the social and economical development plans for the region as basis for the town planning, it is necessary to define the global and acceptable seismic risk level as important parameters for the elaboration of the town plans.
- To classify the structures and other urban elements according to their serviceability period. The definition of the serviceability period of structures is necessary for the seismic risk evaluation.
- To carry out classification according to the importance of the structures.
- To make efforts, during the town planning and designing process, for mitigation of the seismic risk by using all given possibilities, being aware of the fact that it is proportional to the serviceability of the structures, their importance and the seismic excitation level. In this respect it should be, generally, considered that structures with longer serviceability periods and of greater importance be located in zones with lower ground accelerations.

Protection Measures

It has been proved, from the aspect of protection against catastrophic earthquakes, that high concentration of population and material property in towns and settlements is unfavourable, because in case of an earthquake a large number of casualties and considerable damage can be expected. It is considered that earthquake risk is one of the governing factors influencing the population density, therefore it is necessary that:

- Average construction density be less than the one proposed in the general town planning code.
- It is recommended to apply an open construction system.
- The average density should be, in principle, less than the one suggested in the general regulations for such regions.
- The size of the open green areas and recreation and sports terrains can be larger than those proposed in the town planning code, while their distribution should be compiled with the mentioned microzonation.

In seismic areas, it is necessary to pay special attention to the design of the infrastructure works, such as electric power supply, water supply and

sewerage, various gas-lines and stream-pipes, fuel reservoirs, etc., reragsless they run above or underground.

It is necessary, because of the decreasing the possibility for their damage due to earthquakes, the conditions for an efficient aid to the injured and for elimination of the earthquake concequences is improved. In this way the number of eventual casualties and accidents in the post-earthquake period as well as the possibilities for blasts and fires is decreased. In this sense the following is recommended:

- During the design of infra-structure lines, particularly life lines, special attention should be paid to the engineering-geological and the sesmological conditions as well as soil properties.
- The protection measures impose the need for complete or partial water supply by gravity pipe-line systems, should adequate conditions exist, since this system does not require additional power supply.
- Embankments, march and unstable terrains should be avoided for tracing the main lines of all types of infrastructure.
- The ground electric installations should be provided with shut-off devices for the separate regions.

Concerning road network, it should be noted that the planning and design of roads should be considered both from the economical and traffic aspect, as well as from the aspect of planning and design of roads in seismically active regions.

- In the system of roads through a region it is necessary to provide parallel connections, i.e. parallel roads, so that in case one is damaged the other one can be used for the traffic and supply with no disturbance, as well as for the needs of approach to the damaged buildings and giving first aid to the injured.
- To provide, in any case, inter-connection of the regions by different traffic means, which is desirable for the needs of regulation of traffic in post-earthquake critical moments, as well as in case when one kind of trafic means is not functioning.

The evacuation of the population, as well as supply of all most necessary materials, after an catastrophic earthquake, is always an inevitable needs. These requires increase of the traffic, which points out the requirement of special attention when planning the traffic lines in order to provide regular undesturbed traffic even in most critical moments.

All above mentioned recommendations prove the fact that undertaking of protection measures during the process of town planning and designing is far more efficient and rational, than the assessment of the earthquake concequences.

## CONCLUSION

The present experience and the investigations of the behaviour of structures and other elements in the seismic active ares during strong earthquakes, as well as the consequences, show that the prevention against the unfavourable effect of the earthquakes should be initiated from the urbanization phase. That is significantly more rational than assessment of the earthquake concequences.

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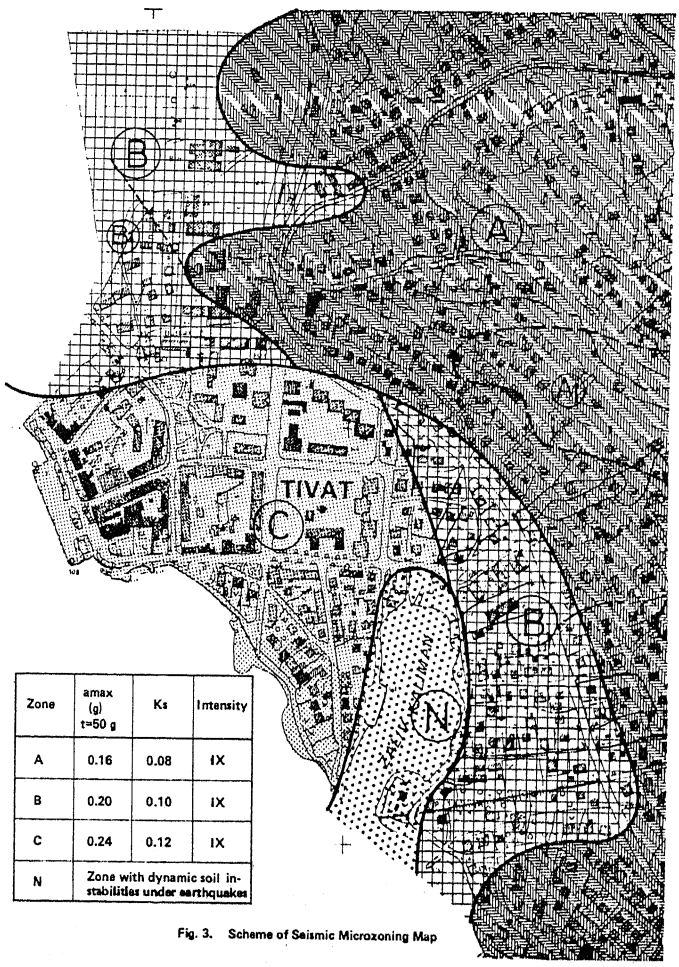


| Zone | amax (g) t=50 g | Ks | Intensity |
|---|---|---|---|
| A | 0.16 | 0.08 | IX |
| B | 0.20 | 0.10 | IX |
| C | 0.24 | 0.12 | IX |
| N | Zone with dynamic soil instabilities under earthquakes | | |

Fig. 3. Scheme of Seismic Microzoning Map