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Some seismic microzoning aspects in protection against earthquakes – Yugoslav experience

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ABSTRACT: Disastrous earthquakes that frequently occur in Yugoslavia are a permanent threat and create enormous losses in human lives, goods and properties. The existing code for design and construction in seismic prone areas adequately treat the problem of elaboration of different seismic maps as a basis for planning and design. However, the lack of unified methodology for elaboration of such maps, especially in the field of seismic microzoning, is a very complex problem. Some of these problems and the experience of seismic microzoning in Yugoslavia shall be presented in this paper.

1. INTRODUCTION

The objective of seismological studies and maps is to provide data on the seismicity of a region or urban areas and to define the seismic hazard on the basis of the existing seismological, tectonic, geophysical, geological and other involved data.

All above mentioned data are necessary for elaboration of various seismological maps (epicentral maps, seismic zoning maps, seismic hazard maps, microzoning maps, etc). These maps have been prepared, depending on whether the purpose of the maps is to present basic data, to present data augmented by judgement, or to specify criteria by design.

It is desirable that engineers know the potential hazard of future events. For this purpose, detailed investigations and studies for definition of seismic hazard level of the given site, are necessary. Generally considered, such studies can be justified only for large important structures such as nucler power plants, large dams, etc. However, even for the design of any other structures in seismic zones data on seismic hazard level are necessary, that is data on the level of the design ground motion for seismic loading. Usually, these data are available from special seismic zonation and microzonation maps developed for certain geographical regions or sites.

The seismic zonation maps giving the degree of seismic hazard in various regions in the future shall provide an important basis for programming of the national economic construction, the land use and exploitation, the earthquake resistant design of engineering structures and for taking measures of earthquake resistance and disaster prevention in urban and rural areas.

Seismic microzoning of urban areas (cities, settlements, industrial complexes, etc.) in respect to methodology and contents offers promising possibilities for preventive earthquake protection. Applying seismic microzoning, zones of different intensity level or ground acceleration are obtained which is direct indication of the effects of future earthquakes in separate zones. In this way a basis for detail investigation of the possible vulnerability level of structure is provided as dependent upon the site seismicity, the local engineering-geological conditions and the methods of construction, creating thus conditions for adopting of corresponding earthquake protection measures as well as measures for seismic risk reduction.

Due to this, there have been various attempts to "solve" this problem of seismic microzonation maps. At this, all known methods and solutions are based on processing of the existing available geological and seismological data and selected models of the theory of probability used for determination of the probabilistics of the earthquake parameters. or elaboration of these maps, the compilation of available data and judgement of knowledgeable geologists, seismologists, earthquake engineers and design engineers is a practical necessity.

Some aspects of the seismic microzoning method used in Yugoslavia have been presented in this paper together with a description and critical review of its application in the physical and urban planning.

2. DEFINITION OF THE PROBLEM

The ever-lasting danger of disastrous earthquakes, which relatively frequently attack the territory of Yugoslavia, emphasizes the need for preventive protection against earthquakes which should start as early as in the stage of the physical and urban design.

Taking into account the actual seismic conditions of the site on which the structures are to be constructed and applying the basic principles of engineering seismology and earthquake engineering in the design can directly influence the reduction of earthquake consequences and the existing level of seismic risk.

The Codes for design and construction in earthquake prone regions is one of the basic earthquake protection measures. However, the technical provisions could not cover all the fields and stages of planning and design for improvement of the earthquake protection level. They also could not cover all the seismic effects influencing directly the behaviour, vulnerability and stability of structures.

The seismic protection measures included in the aseismic design Codes could not provide the necessary protection level to the society since they could neither prevent nor significantly decrease the indirect damage and economic consequences, which are considerably larger and more serious in the urban and technically developed regions, compared to the damage to structures.

It is therefore necessary, besides improvement of protection measures within the technical provisions, to search for new ways and aspects of seismic protection in all technical fields for increasing the level of both protection and reliability by introducing small investments which will be used in a more efficient and rational way.

The elaboration of seismological studies and maps for seismic microzoning purposes as a basis for planning and design is one of the most rational forms of earthquake protection. The objective of the seismic microzoning is, based on the results of the seismological, geological, geophysical, engineering-seismological and other investigations and their inter-relations, to define parameters and criteria for rational urban planning and architectural-structural design. In other words it enables a wide application of the latest achievments of the above listed sciences in planning of both conditions and criteria of earthquake protection and their accomplishment.

3. SEISMIC MICROZONATION - A BASIS FOR UNDERTAKING RATIONAL PROTECTION MEASURES

Among the others, one of the basic prerequisites for urban planning and design in seismically active regions is microzoning mapping with all necessary enclosures. This map provides for further reduction of earthquake effects.

The map of seismic microzoning of urban areas (Fig.1) presents the zones, and eventual subzones, according to the expected maximum seismic intensities of the MCS scale. The characteristics of local soil conditions are also marked on this map, which gives a clear insight in the possibilities for construction. This is why the map of seismic microzoning of an urban area clearly shows the possibilities of the most rational planning of the urban area during elaboration of physical concentration of the urban planning. The adequate land usage in the physical plan is one of the measures for protection against destructive earthquake effects. This map gives information on the seismically most and least favourable construction grounds, the location of fault zones, etc.

The aim of seismic microzoning of an area is to determine the basic parameters and criteria for rational urban planning and design on the basis of results obtained from engineering-seismological and other studies. The design of towns itself, based on seismic microzoning results, may guarantee optimum protection measures and reduction of damages in future earthquakes.

By its nature and contents, seismic microzoning offers various possibilities for protection against earthquakes. It enables a wide application of contemporary scientific accomplishments in definition of criteria for the level of seismic protection in all aspects and all phases of planning and design. Seismic microzoning also enables obtaining of more reliable seismic parameters and criteria for design of buildings which is a qualitative supplement in the part of technical regulations that is usually generalized. It also gives evidence for more complex and detailed studies of the seismological-geological characteristics of the terrain and their influence on earthquake effect parameters. This is the way that the problems of seismic protection can be more adequately and rationally solved in the phase of elaboration and realization of physical, urban and construction planning and design.

During urban planning and design, i.e. during elaboration of urban plans, attention is paid to more detailed analysis of seismic danger, mainly in order to reduce even more the existing seismic hazard.

Seismic microzoning is also a basis for further study of the possible vulnerability degree of all types of construction buildings depending upon actual seismic effects, seismic hazard parameters and seismic hazard level. Accordingly, it enables on-time planning of the required level and measures for seismic protection, as well as the corresponding measures for quick and efficient mitigation of damages and caused consequences.

Seismic protection of population, material and cultural property is a continuous process including all phases of planning and design of urban areas and construction of buildings. The results of seismic microzoning are applicable in:

- elaboration and realization of physical plans of regions and communes;
- elaboration and realization of general and detail urban plans and design of urban, suburban and other areas;
- design of important, costly and technologically complex structures, buildings whose failure would be dangerous for the environment, buildings with technologically specific characteristics and usage, for which technical regulations

demand special design conditions and testing of their stability and vulnerability;
- design of all types of buildings in accordance with technical regulations;
- definition of soil instability potential for different levels of seismic hazard and risk;
- definition of conditions and criteria of seismic protection, and
- planning of required conditions and measures for quicker and more efficient reduction of expected damages and consequences due to earthquakes.

Considering the importance and possibilities of seismic protection of urban areas based on the results from seismic microzonation, as well as the fact that undertaking of protection measures in the phase of design is far more efficient and rational than assessment of earthquake effect consequences, the following is recommended:

During planning and design process, efforts should be made to comply, as far as possible, to the land use pattern, i.e. 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. That is, construction and population density should be decreased with the increase of those effects.

The problem should be pointed out here of the existing structures, of urban units, with their specific character, which have not been constructed in compliance 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 solutions will have to be applied in the sense of the basic town planning concept and the seismic conditions.

4. SEISMIC MICROZONING PROBLEMS IN YUGOSLAVIA

The existing code for design and construction in seismic prone areas adequately treats the problem of elaboration of different seismological maps as a basis for planning and design. However, the lack of unified methodology for elaboration of such maps, especially in the field of seismic zoninng, is a very complex problem. At present, several well known seismic microzoning methods are used in Yugoslavia, out of which the following should be mentioned: engineering-geological method, the method of Prof.S.Medvedev (improved later by V.V. Popov and G.N. Nazarov), Kanai's method, the analytical method developed at IZIIS, Skopje, etc.

Considering the great number of factors accompanying the earthquake phenomenon and their effects upon the ground surface, it is very hard to define a seismic microzoning method which will solve all the aforestated problems.

Therefore, several methods solving one or mostly few seismic microzoning problems are proposed for practical application. This gives the possibility to solve a problem by applying several methods, each being equally good for its purpose. On the other hand, this is the reason why it is possible to solve a problem by using a certain method, while it is impossible by another.

A special reference should be given here to the results shown in these maps: (1) with different intensities or accelerations, (2) dynamic stability or instability of ground in certain zones, eventually zones where liquefaction is expected, (3) zones of different land use, etc.

Depending on the desired objectives, the maps mentioned above can be used for seismic zoning either separately or combined. During the last 25 years, due to the difficulty in quantitative describing of the earthquake intensity and the unsuitability of the basic data derived from these kinds of maps for the dynamic analysis and the design of buildings, greater attempts were made to show the peak acceleration, velocity and displacement of the ground motion instead of the intensity on the seismic zoning maps. At the same time attempt was made to include into these maps information on the return periods of the physical parameters of the ground motion within a given time interval, the statistical models used to determine these return periods, the reliability of these models and other. These efforts, without any doubt will provide better solutions in Yugoslavia, where dynamic analysis methods are required and where practicing design engineers have reached a certain technological level.

It can be concluded from all the above mentioned that the methods, techniques and the parameters presented on these maps are of great importance. The technical limitations in space of this paper do not allow us to present in more detail some of the methods and maps. We present here only two seismic microzoning maps with different parameters. Figs. 1 and 2 show a map with zones of different intensities, while Fig.3 presents a map of dynamic instability potential. The purpose of these maps is to illustrate some results of the investigations related to seismic microzoning of some towns in Yugoslavia.

5. RELATED PROBLEMS AND CONCLUSIONS

A seismic map is a map predicting the geographical distribution of certain quantity, either without time limitation or during a specified period of time. There is a principal question which everyone will have it clarified before starting the work, i.e. what information will the zoning map provide? The answer involves problems related to the existing building codes or to the requirements of regional planning.

There are several weak points of the procedure. First is the lack of seismological, geological and other information on the processes governing the origin of earthquakes and propagation of strong motions in real media. At the begining of the work a problem is faced of definition of potential earthquake source and of the reccurrence of strong shocks. It is decided to consider all regions where earthquakes have originated so far as regions of at least the same activity in future. Other problems are to delineate the potential regions which now display only low activity and to estimate the future frequency of occurence of strong earthquake.

In this paper some aspects, ideas and experience from Yugoslavia on these problems are presented. On this basis the following conclusions are made:

- Seismicity, earthquake statistics, seismotectonics, geophysics, geotechniques and seismic hazard studies are the most important steps for the realization of seismic microzoning map of given urban areas;
- Seismic microzoning has become one of the most important subject of seismic studies in Yugoslavia during the past 25 years and will most likely continue to be so as the economic development increases. The subject of the seismic microzoning is mainly a problem of seismic hazard analysis.
- Seismicity modelling of a region of high seismic activity has a great influence upon the final results - the peak ground acceleration or intensity. The existing data (seismological, geological, etc.) as well as the time period for which reliable data exist are not a sufficient basis for forecasting and complete estimation of the possible consequences induced by future earthquakes.
- The mathematical model of the seismicity, the seismic hazard analysis and microzoning mapping technique, considered in this paper, is one of the possible solutions of the problem. It involves many theoretical and practical issues which should be taken into account.

More detailed investigations are still needed in all fields of science (seismology, mathematics, earthquake engineering, economy etc.) in order to define the actual theoretical scope for the purpose of definition of a general, complete seismic hazard model for practical purposes. Due to the necessity for introduction of certain assumptions and simplifications, the present solutions of seismic microzoning should be treated as incomplete ones.

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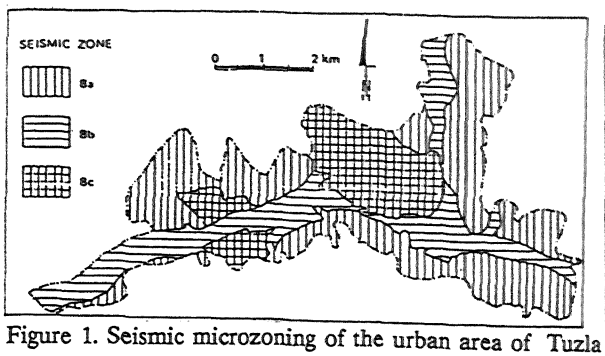


Seismic Design Parameters for Seismic Zones

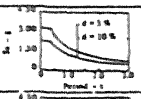
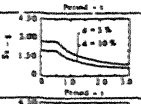
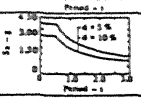
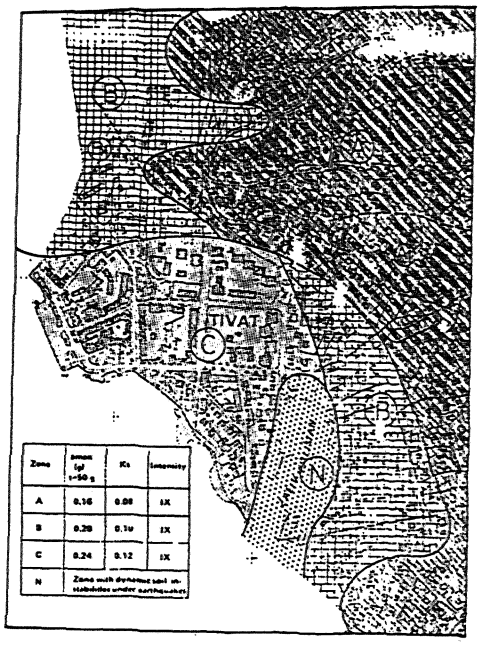
Seismic zones	Design earthquakes	a_{max} (g)	Seismic coefficients K_h	Design spectrum
Ba	Z_1	0.150	0.050	
	Z_2	0.215	0.055	
Bb	Z_1	0.150	0.050	
	Z_2	0.225	0.055	
Bc	Z_1	0.175	0.060	
	Z_2	0.255	0.065	

Figure 1. Seismic microzoning of the urban area of Tuzla



Zone	a_{max} (g) $t=50$ s	K_h	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		

Figure 2. Seismic microzoning map of the town of Tivat

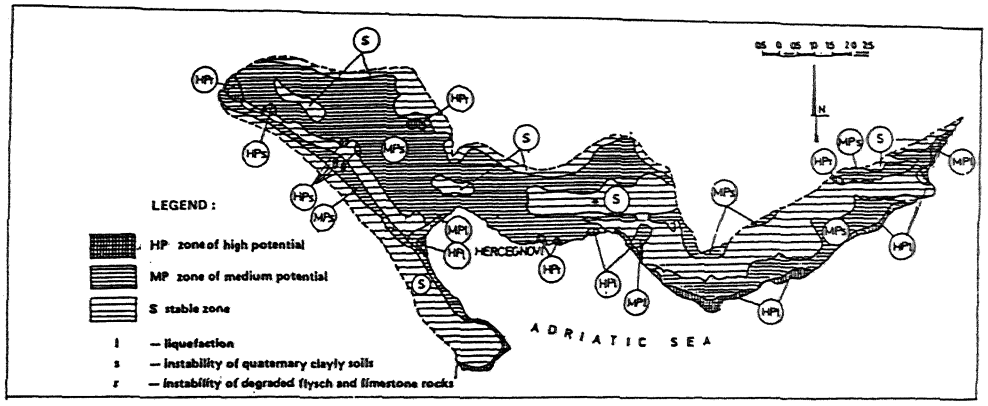


Figure 3. Microzoning of the town of Herceg Novi. A map of dynamic instability potential of the soil medium for the expected future earthquakes