REASONS FOR DAMAGES AND DESTRUCTIONS CAUSED
BY RECENT EARTQUAKES AFFECTING BULGARIAN TERRITORY

BULGARİSTAN'I ETKİLEYEN SON DEPREMLERDE HASAR VE YIKIMIN NEDENLERİ

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ABSTRACT

During the last 15 years several earthquakes have struck Bulgarian territory. They have caused serious damages and destructions in some towns and villages.

The engineering analysis of the damages and the destructions in the buildings and structures was performed by a great number of Bulgarian specialists. A survey of obtained results is presented in this paper, predominantly on the basis of two earthquakes: the one in 1977 with epicentrum in Vrancea, Roumania and the other in 1986 with epicentrum in Gorna Oryahovitza seismic zone, the central part of Notrhern Bulgaria.

The reasons for the damages in the buildings and structures are summarized in 6 sections: normative base, designing, structural materials quality, performance of constructions, controlling the construction quality, inadequate exploitation. Special attention is focused on the necessity and the importance of determining in advance the seismic characteristics of the site.

GENERAL CHARACTERISTICS OF THE EARTHQUAKES AND THE GEOLOGICAL CONDITIONS

Working out a seismic zoning map of Bulgaria in view of the maximium intensity reached in the last 100 years will show that almost the whole country consists of seismic zones with intensities of VI to X degree according to the MSK scale (fig.1).

Two eartquake series struck the Gorna Oryahovitza seismic zone in 1986. The first one has started on 21 February, having a main shock of magnitude M=5.1 and epicentral intensity of VII to VIII MSK

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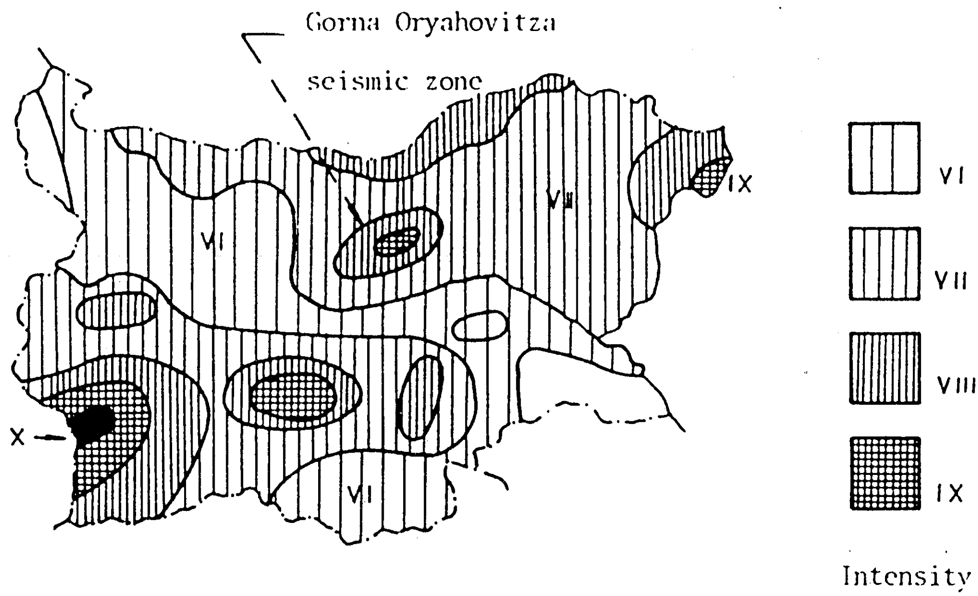


Fig. 1. Seismic zoning map of Bulgaria according to maximum intensity reached in the last 100 years

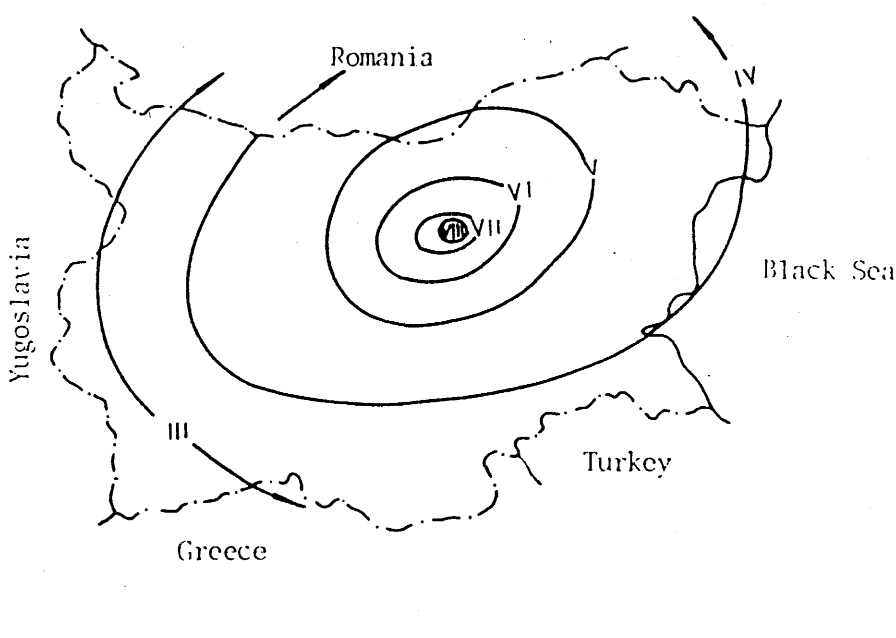


Fig. 2 The isoseismals map of December 1986 earthquake

degree. The second one has started on 7th of December, having a main shock of M=5.7 and epicentral intensity of VIII MSK degree. The epicentral zones of both series are located in the region of the town of Strazhitza. The focal depth is 7-15km. Predominant vibration periods of the seismic movement are from 0.2sec to 0.5 sec.
the maximum horizontal accelerations in the epicentral zone are about 0.3g.

The isoseismal map of December 1986 earthquake shows that it has been felt all over the Bulgarian territory (fig.2). The eartquakes caused serious damages and destructions. More than 24000 residential, public, industrial and agricultural buildings were affected in more than 20 towns and villages. Half of them have been declared unfit for dwelling and the other half needs serious strengthening or repairing.

The Gorna Oryahovitza seismic zone relief is predominantly flat in its northern part and hilly and low-moutaneous in its southern part.

From an engineering-geological point of view the territory is a system of rocks with different properties. Their varied combinations in horizontal direction and in depth determines the non-homogeneity and the anisotropy of the medium. The upper ground part in which the buildings are usually founded often consists of loess and different clays. This complicates the engineering-geological conditions for construction. There are landslides in many places on the slopes. There are also areas of shallow underground waters which contribute to the seismic intensity increasing.

The Vrancea earthquake of March, 4th, 1977 had o focal depth of about 110 km and a multishock mechanism with a main shock magnitude 7.2. Maximum horizontal accelerations of 0.2g on the N-S direction and 0.16g on the E-W direction as well as a vertical acceleration of 0.1g were recorded at INCERC, Bucharest. The seismic movement shows predominant vibration periods of 1sec to 1.6 sec (in Bulgaria up to 2.4sec). That earthquake affected the whole Bulgaruan territory (fig.3) with intensities of IV to VIII degree. One can see that a characteristic feature of the map is the asymmetric intensity distribution.

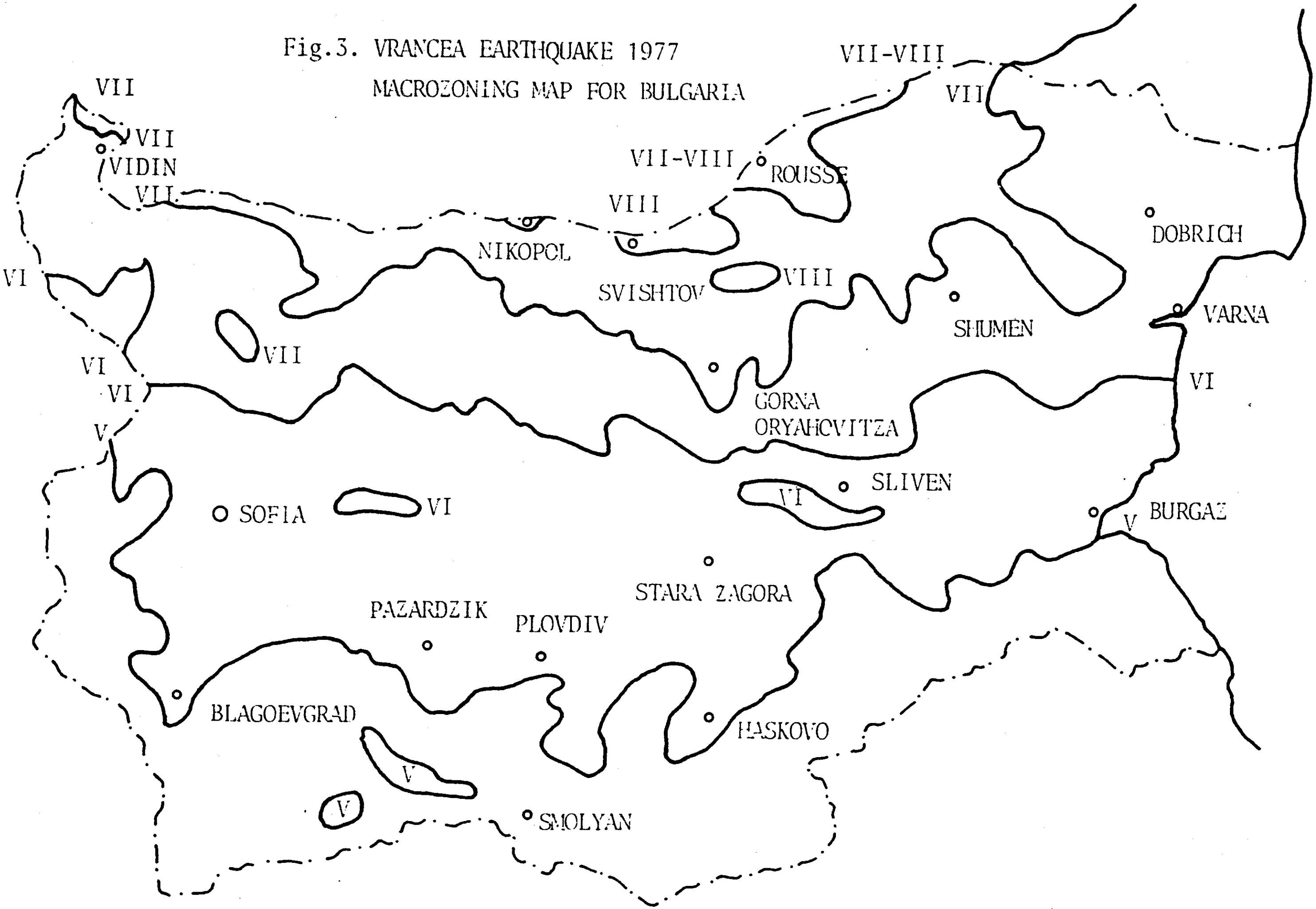
It is clear now that the two described earthquakes (of 1977 and 1986) have very different seismic characteristics, especially as regards the predominant vibration periods of the seismic movement. The great variety of these periods (of 0.2 sec to 2.4 sec) covers the natural periods of the greater part of the existing buildings and structures. Thus it is possible to verify their behaviour during an earthquake for unfavourable conditions caused by the close values of the seismic and natural vibrations.

SUMMARIZED ANALYSIS OF THE REASONS FOR DAMAGES OF THE BULIDINGS AND STRUCTURES

The engineering analysis covered the residential, public, industrial and agricultural buildings,as well as the other different

Fig.3. VRANCEA EARTHQUAKE 1977

MACROZONING MAP FOR BULGARIA



structures (chimneys, silos, bridges, roads and railways,etc.). It is apparently not possible to present all the details concerning the obtained results in this only paper. That is why a try to present the reasons for the damages and the destructions in a summarizing form in 6 sections is done. These sections are: normative base, designing, structural materials quality, performance of construction,controlling the construction quality, inadequate exploitation.

Normative Base

The reasons for damages and destructions due to the normative base are predominantly as follows:

1.Lack of sufficient seimological information as a basis of proper evaluation of the seismic intensity of the region. For example some regions have been regarded as of VI or VII seismic intensity until 1977 and VII or VIII seismic intensity thereafter. It means that the design and construction requirements for those regions were unsufficient before 1977.

2.Unproper determination of the design seismic loading of the structures as a result of imperfect design methods of the original code which reflect the current knowledge level. A vast number of buildings and structures have been built in the affected regions according to those design methods.

3.Lack of normative provisions requiring construction projects for low rise individual residential buildings. Practically the greater part of that type of buildings are built without engineering analysis.

4.Lack of normative reqiurements for assessment of seismic risk of the construction sites of important structures and new urban areas. In this case macrozoning map is not sufficient and the requirement for a seismic microzonation has to be compulsory.

Designing

The more important reasons for damages and destructions due to unproper designing are:

1.Underestimating the significance of local geological conditions. In many cases the designer does not require detailed information about them. There even exist buildings constructed on slides.

2.Wrong motivation conceptions for design solutions regarding the seismic safety of building structures. This is because of the lack of experience of some civil engineers and architects. The projects are often been elaborated in very complicated and non-symetric forms. They often lack columns in the corners of the building, a band between the walls and the floor and connections between the separate floor elements. Weak connections between the outer walls and the inner elements in the prefabricated buildings are other shortcomings.

3.Insufficient width of the aseismic joints, etc.

Materials

The reasons for damages and destructions because of the materials are:

1.Use of concrete with strength lower than the designed one.

2.Use of fourfold bricks (called in Bulgaria effective ceramics) for bearing walls. It is not possible with these bricks to make a monolithic wall because the vertical joints between them remain always without mortar. Such a wall is not good from the dynamic point of view.

3.Use of mortars of lower strength or use of clay instead of mortar.

4.Use of adobe in the old buildings of some villages.

Performance

There are many reasons for damages and destructions due to the performance.

1.Non filling-in with mortar of the masonry joints.

2.Lack of or poorly performed masonry bandages.

3.Lack of connection between the masonry and the reinforced concrete skeleton along the horizontal and vertical joints.

4.Non filling-in or a low quality fillinig-in and grouting of joints in prefabricated structures.

5.Poor quality performed connections between the reinforced concrete columns and beams.

6.Disregarding the requirements of the working projects (lack of stirrups,nonobservance of the distances between them; poor compaction of the concrete; non observance of the required lengths for anchoring and fitting together).

7.Non-observance of the normative reqirements for concreting at low temperatures.

8.Poor quality performance of weldings and non-observance of their prescribed lengths and cross section.

Control

The shortcomings of the control authorities are:

1.Insufficient control over the construction materials (sand and gravel, bricks, mortars, concrete. etc.).

2.Insufficiently qualified technical control over the construction projects from an earthquake point of view.

3.Insufficient control over the quality of performance of the part of the designer and the investor.

Exploitation

Serious omissions during the exploitation have in some cases exercised substantial influence on the seismic resistance of the buildings. Unqualified changes reducing the bearing capacity of the structures (moving or driving out of the walls,cutting off of bearing reinforcement in columns, beams, etc.) have been practiced. The unsatisfactory state of the water- and canal network in some of the buildings has led to watering and settling of their foundations.

RESULTS OF THE SEISMIC MICROZONING OF THE TERRITORY OF SEVERAL TOWNS AND VILLAGES

A programme for restoration of the affected towns and villages was worked - out soon after the earthquake in 1986 in the Gorna Oryahovitza seismic zone. The respective state authorities set as a top urgent task that seismic microzoning of the territory be accomplished and taken into cinsideration during the designing and reconstruction.

Such seismic microzoning was made for 12 towns and villages. The final results of the seismic microzoning (table 1) represent a more accurate determination of the values of two coefficients included in the design seismic force determination formula. These are: the seismic coefficient K_s and the dynamic coefficient β.

The seismic coefficient K_s is the ratio of the accepted for each seismic intensity design ground acceleration to the gravity acceleration. According to the effective in the country now "Norms for design of Buildings and Structures in Seismic Regions" this coefficient is equal to 0.10 for some of the towns and villages in question and equal to 0.15 for the rest. The seismic microzoning results show that for places with seismic coefficient 0.10 according to the Norms, values varying from 0.11 to 0.14 should be accepted, i.e. an increase from 10 to 40%. For places with seismic coefficient 0.15 according to the Norms, values varying from 0.15 to 0.23 should be accepted, i.e. an increase from 0 to 53%. In other words except one of the villages where the microzoning seismic coefficient prouved to be equal to that of the Norms, for all the other places an increase from 0.10 to 53% is required.

The dynamic coefficient β depends on the natural vibration periods of the structures and on the respective ground conditions. For the affected places the Norms prescribe a maximum dynamic coefficient β=2.5. The seismic microzoning results show values varying from 2.65 to 3.20 for the different places, i.e. the coefficient β increases with 6 to 28%.

The above new values of both coefficients were prescribed as compulsory for non-standart design of residential buildings, hospitals, schools, kindergardens, cultural centres, industrial buildings, etc. The combination of both coefficients for the different places led to an increase of the seismic loading from 12 to 84%.

The above results show the great signifisance of the seismic microzoning. It is evident that some buildings designed and constructed according to the Norms, were not able to resist to the expected seismic loading.

Table 1. Coefficients K_s and ß for Some Towns and Villages

№	Name of town/village	According Code		According microzoning		Code	Micro-zoning	ratio $K_s.ß$ (microz.) / $K_s.ß$ (code)
		K_s	ß	K_s	ß	$K_s.ß$	$K_s.ß$	
1	2	3	4	5	6	7	8	9
1	Assenovo	0,15	2,5	0,19	3,2	0,375	0,60	1,60
2	Bregovitza	0,15	2,5	0,22	2,8	0,375	0,61	1,33
3	Goritza	0,15	2,5	0,23	3,0	0,375	0,69	1,84
4	Voditza	0,10	2,5	0,14	3,0	0,250	0,42	1,68
5	Kovathevetz	0,10	2,5	0,13	2,8	0,250	0,36	1,44
6	Kreptha	0,10	2,5	0,11	2,8	0,250	0,31	1,24
7	Manastiritza	0,15	2,5	0,22	3,0	0,375	0,66	1,76
8	Mirovo	0,15	2,5	0,21	3,2	0,375	0,67	1,78
9	Opaka	0,10	2,5	0,12	2,8	0,250	0,33	1,32
10	Popovo	0,15	2,5	0,15	2,8	0,375	0,42	1,12
11	Chapaevo	0,15	2,5	0,20	2,8	0,375	0,56	1,49
12	Strazhitza S	0,15	2,5	0,18	2,65	0,375	0,48	1,27
13	Strazhitza N	0,15	2,5	0,21	2,8	0,375	0,588	1,57

The table is valid for T = 0 ÷ 0,5 sec.

CONCLUSIONS

The consequences of the described earthquakes were a lot of damages and destructions and unfortunately loss of human lives. Each case had its own main reason but for most of the cases a combination of the different reasons is applicable. Those reasons however were not inevitable. Special control mechanisms are needed over design and constructions stages. Sufficient safety against possible earthquakes can be achieved in case everyone related to the problem does his own job properly. In this respect the role of the specialists of earthquake engineering and especially of the scientists is determinant. They have for example to urge the respective authorities to provide the necessary funds for research and especially for detailed microzoning studies. For in the long run these funds will recover keeping buildings and structures safe and reducing to a reasonable minimum the loss of human lives in case of future earthquakes.

The cooperation among earthquake engineering specialists from different countries is also of great importance for reducing the erthquake consequences. It is high time that this cooperation becomes more active involving permenent joint work upon various problems of mutual interest. This is especially important for neighbouring countries of one and the same seismic region.

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BULGARİSTAN'I ETKİLEYEN SON DEPREMLERDE HASAR VE YIKIM NEDENLERİ

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ÖZET

Son 15 yıl içinde Bulgaristan'da, bazıları şehir ve köylerde ciddi hasar ve yıkımlara neden olan bir çok deprem oldu. Bina ve yapılardaki hasar ve yıkımların mühendislik analizi çok sayıda Bulgar uzman tarafından yapılmıştır. Bu yazıda, elde edilen sonuçların bir değerlendirmesi sunulmuştur. Bu sonuçlar genel olarak, episantrı Romanya Vrancea'da olan 1977 depremi ile episantrı kuzey Bulgaristan'daki Gorna Oryahovitza sismik bölgesinde yer alan 1986 depremlerine dayanmaktadır.

Binalar ve diğer yapılardaki hasar sebepleri 6 bölümde özetlenmiştir: normatif temel, tasarım, malzeme kalitesi, yapıların performansı, inşaat kalite kontrolu, uygun olmayan kullanım. Çalışmada ayrıca bölgenin sismik özelliklerinin önceden belirlenmesinin önemi ve gerekliliği üzerinde de durulmuştur.