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EFFECTS OF VRANCHA EARTHQUAKE OF 4 MARCH 1977 ON THE TERITORY OF BULGARIA

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SUMMARY

The spectral characteristics (predominant periods,Fourier transforme spectra,response spectra) of Romanian earthquake on 4 March 1977 are analysed in respect to explain the couses of destruction of buildings located 200-500 km from epicentra.

Effects of the earthquake on masonry buildings ,reinforsed concrete frame,large panel and industrial buildings are analysed.

SOMMAIRE

Les characte ristiques spectrales (periodes predominants,spectre de transformation de Fourier,spectre de response) du tremblement de terre a Roumanie de 4.III.1977,sont analysies. Ces characteristiques sont utilisees comme explication des facteurs qui ont produit les degats des batiments et des constructions,situes a environ 200-500 km de l' epicentre.

Les effets du tremblement de terre sur des maconries des batiments fait on beton arme monolitique et prefabrique,sont analyses.

ZUSAMMENFASSUNG

Die spectraliche Charakteristiken (die dominierende Perioden, das Fourierisches Transformationspektrum,das Responspektrum) des Rumanischen Erdbebens vom 4 Marz 1977 sind analysiert. Diese Charakteristiken sind notwendig um die Zertorungsgrunde der Bauwerken, die 200-500 m vom Epizentrum entfernt sind,festzustellen.

Der Einfluss des Erdbebens uber Mauer-und stahlbetonwerke (monolithische und aus Fertigbauteile) ist beschrieben.

1. INTRODUCTION

The earthquake of 4 March 1977 with epicenter Vrancha-Romania, focal depth of 110 km and magnitude 7,3 had an effect on the terito ry of Bulgaria with intensity IV-VIII according to MSK-64 scale. This earthquake colapsed few new reinforce concrete buildings, heavily damaged hundreds and craked towsends. Many tall buildings in Sofia, located 450 km from epicenter, were significantly craced and some of them had to be repared. Three R.C. frame buildings in Svistov on Danube bank with flexible first storey were complitely colapsed and kiled 138 habitans.

The earthquake have had an strong effect over the all teritory of Bulgaria damaged many old and new modern residential and industrial buildings built by monolitic reinforce concret and precast panels and elements. This is the reason the effects from the earthquake to be analysed and conclusions for improvment of the earthquake resistant designing to be suggested.

2. SPECTRAL CHARACTERISTICS OF VRANCHA EARTHQUAKE

The specific mechanism of Vrancha earthquake with focal depth of 110 km had generated seismic waves with long predominant periods 1-2,4 sec which strongly effected the tall and flexible buildings up to 500 km.

On the accelerograme recorded in Bucharest (INCERC), at distance 170 km from epicenter, can be seen tipical sinusoidal character of the motion after 18 sec for both NS and EW components (fig.1). The accelerograme in Nish (453 km from epicenter) (fig.2) contain similar long period motion combined with short period waves specified by the geological conditions.

The Fourier transform spectra from Vrancha earthquake for Bucharest [1] and Nish [2] records and experimentaly determined period [3] at right bank of Danube river (300 km from epicenter) are given on (fig.3). It is evident that specific deep geological conditions with short natural predominant periods for surface layers generate aditional short motions (fig.2). Well known filtration of the short period waves with distance is not observed in this case. There are some regions on the teritory of Bulgaria which generate short period motions and others one-long periods. This fact was confirmed by the behaviour of the structures with diferent natural periods located at different ground conditions.

The response spectra for Bucharest record NS componen, El Centro 1940 NS component and Svishtov NS probable component at 0% critical damping are given on (fig.4). It is evident that Vrancha earthquake effect significantly the flexible structures with natural periods $T > 1$ sec. On this bases can be explaned the large numbers of the demages in flexible structures. In some specifc regions smal buildings of one-two storeys had been heavyly damaged

The isoseismal map of Vrancha earthquake on the teritory of Bulgaria (fig.5) is influenced significantly by the geological conditions-specialy on alluvial deposits at the rivers valey. The most affected area-right bank of Danube is characterised by alluvial deposits and loessoidal surface layers of thikness 5 to 30 m.

3. EFFECTS OF THE EARTHQUAKE ON THE BUILDINGS

The eartquake of 4 March 1977 damaged mainly nondesigned for earthquakes buildings and structures. The buildings designed for earthquake intensity VII or VIII got nonstructural cracks only in infilling walls, joints and so on.

3.1. One-two storeys brick masonry buildings

In the most effected area-Svistov (point 1 on fig. 5) one storey brick masonry buildings did not get any cracks. Two storey very old buildings (fig. 6) with wooden floors did not suffured significantly. Some of them got small cracks (fig. 7)Some old buildings from last century (fig. 8) not designed for earthquakes but well built with steel conections between walls were damaged mainly in connections between timber roofs and masonery. In some other areas (point 2 on fig. 5) one and two storeys masonry buildings were heavy damaged. Those buildings had been built with low strength bricks and mortars (mud or lim-sand),timber floors and roofs non conected well with walls(fig. 9).

The damages of this type buildings in diferent areas depend of geological conditions and specialy of predominant periods of surface layers.

3.2. Reinforce concrete frame buildings with flexible first storey

The most suprising effect of this eartquake was the total colaps of three reinforce concrete buildings without shear walls in first floor. This colapse can be explained by specific response spectra with maximum at $T > 1$ sec (fig. 4), sinosoidal exitation in both directions, large horizontal displacements and additional influence of $P-\Delta$ effect on the bending moments into the columns.

The fifth storey office building (fig. 10) is tipical building with flexible first storey. The existing of shear walls at the stairs only develop additional rotational effects and reserve partly only first two storeys at the stairs (fig. 11). The cilindrical columns of the building are well designed (fig. 12) but connections between girders and columns did not forme space resisting frame for horizontal exitation. The small length of down girders steel bars into columns (fig. 10 b) was not capable to bear suficient bending moments from the earthquake. Similar construction had the sixt storeys public residential building wich was colapsed on the same way (fig. 13).

The nine storeys apartment building with shops (without shear walls) into first storey was colapsed as previous two buildings (fig. 14). Another two nine storeys buildings with the same construction but with masonry shear walls in first storey have resisted very well to the earthquake (fig. 15).

One more example of distortion this type construction is the total colapse of industrial bunker constructed like renforce concrete box suported on four R.C. columns (height-6m).

Many reinforce concrete frame buildings and package lift-slabs buildings with infiling masnry walls were cracked mainly in walls never maind they were not designed for earthquake.

3.3. Large panel and precast buildings

Many large panel buildings were effected by the earthquake but of the reason of low natural periods ($T \approx 0,4$ sec) they did not get any damages. Not designed for eartquake large panel buildings in some regions were lightly cracked in horizontal joints and corners of the doors.

The damages in many industrial buildings were mainly from bed conections between roof trusses and columns (fig.16) between roof ,wall panels and columns.

4. CONCLUSION

The specific spectral characteristics of Vrancha earthquake of 4 March 1977 effects mainly flexible structures. In some regions with rigid ground conditions the exitation was strong on small rigid buildings. Many tall buildings in Sofia (about 20 storeys) located on aluvial ground were cracked and some had to be repared. This super long distance effect of Vrancha earthquake is influenced from specific mechanism of the earthquake and deep geological conditions of respective regions. The buildings with flexible first storey have to be designed taking into consideration the large displasiment of the ground, long distance effect and resonance from sinosoidal waves. In the regions with longe distance effects this type of construction have to be avoid.

Large panel and precast constructions non designed have resisted very well to this earthquake. Special attantion have to paid to the quality of realization on place of the joints between separate elements.

Earthquake resictance designed and well built constructions, according to the normes, have resisted very well to the earthquake.

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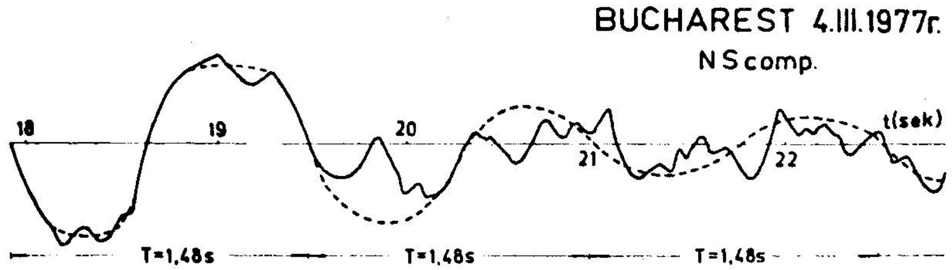


fig. 1

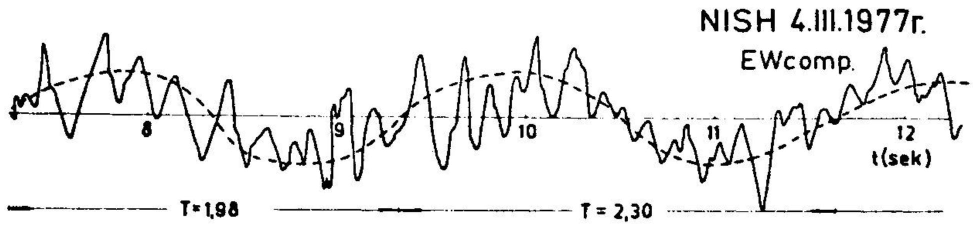


fig. 2

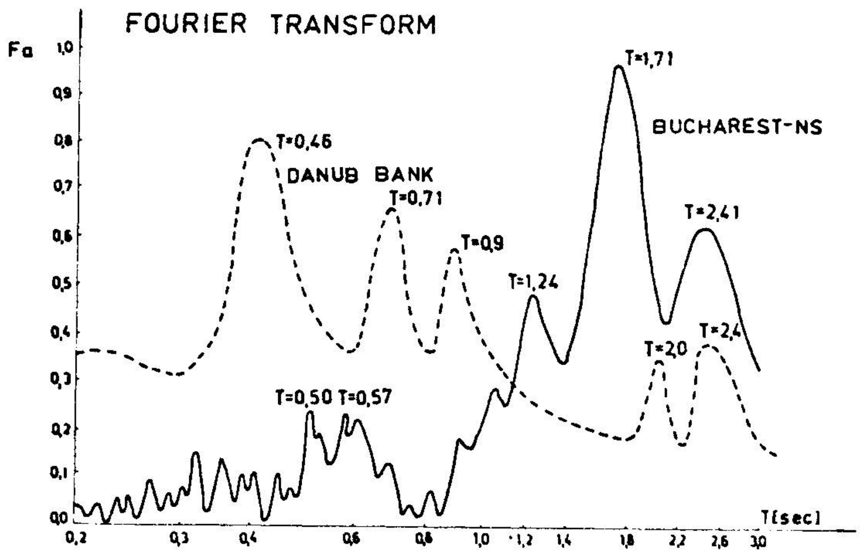
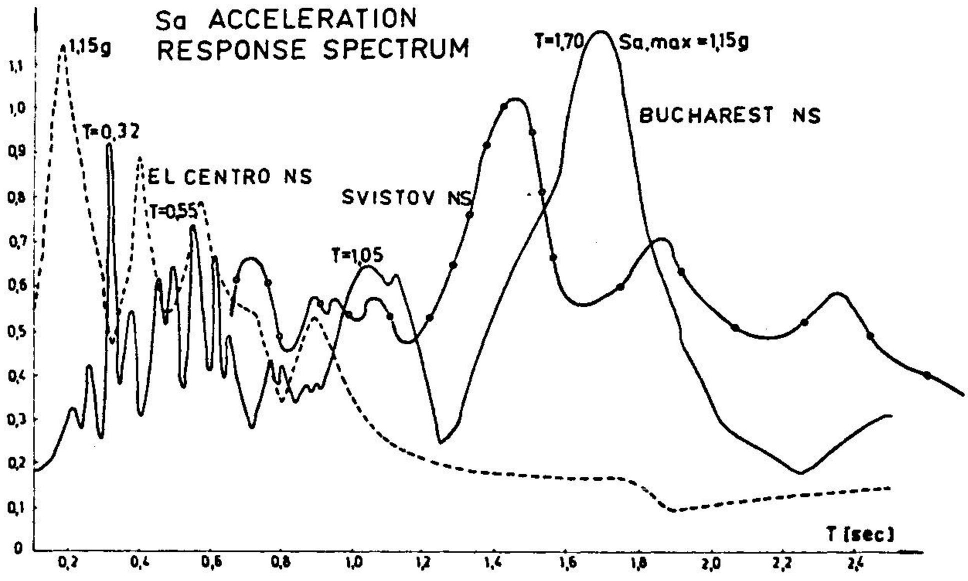


fig. 3


Sa ACCELERATION
RESPONSE SPECTRUM
1,15g
T=0,32
EL CENTRO NS
T=0,55
SVISTOV NS
T=1,05
T=1,70
Sa,max =1,15g
BUCHAREST NS
T [sec]
0
0,1
0,2
0,3
0,4
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0,6
0,7
0,8
0,9
1,0
1,1
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0,6
0,8
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1,6
1,8
2,0
2,2
2,4

fig. 4

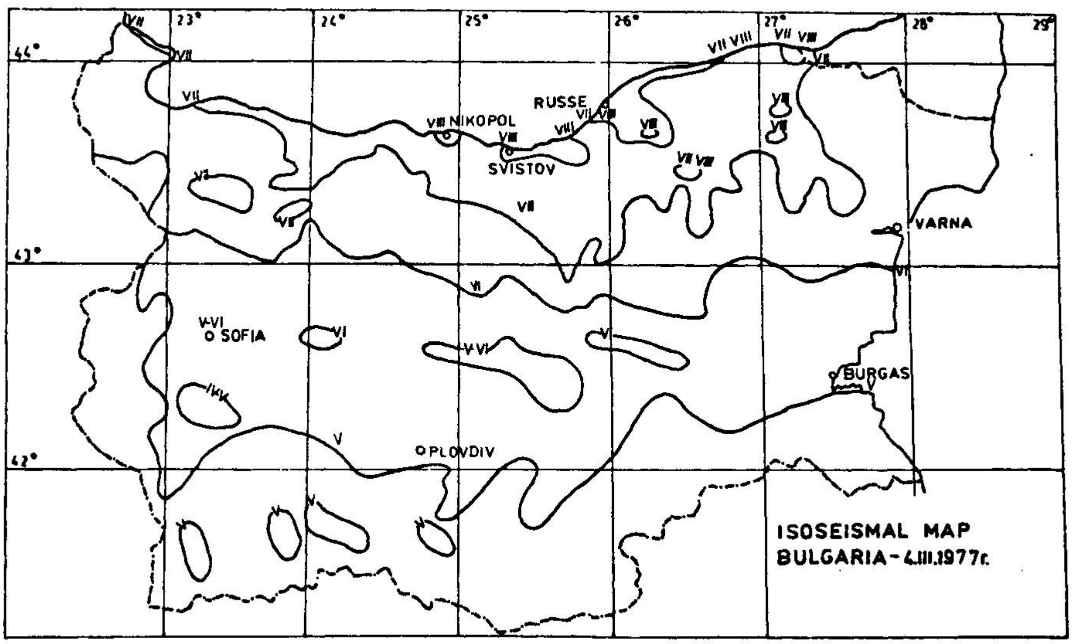
23°
24°
25°
26°
27°
28°
29°
44°
43°
42°
NIKOPOL
RUSSE
SVISTOV
VARNA
SOFIA
BURGAS
PLOVDIV
ISOSEISMAL MAP
BULGARIA - 4.III.1977r.

fig.5

fig. **6**

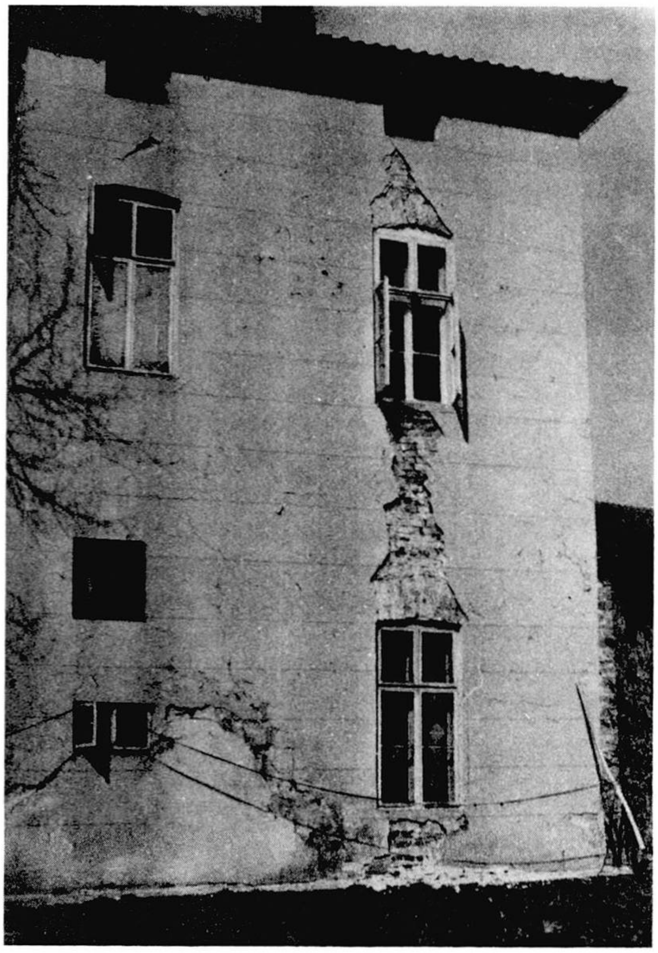

fig. **7**

fig. 8

fig. 9

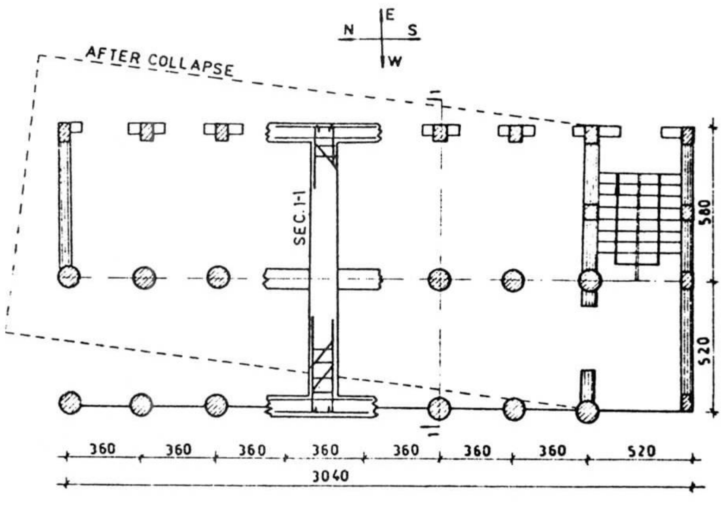

fig.10

fig. 11

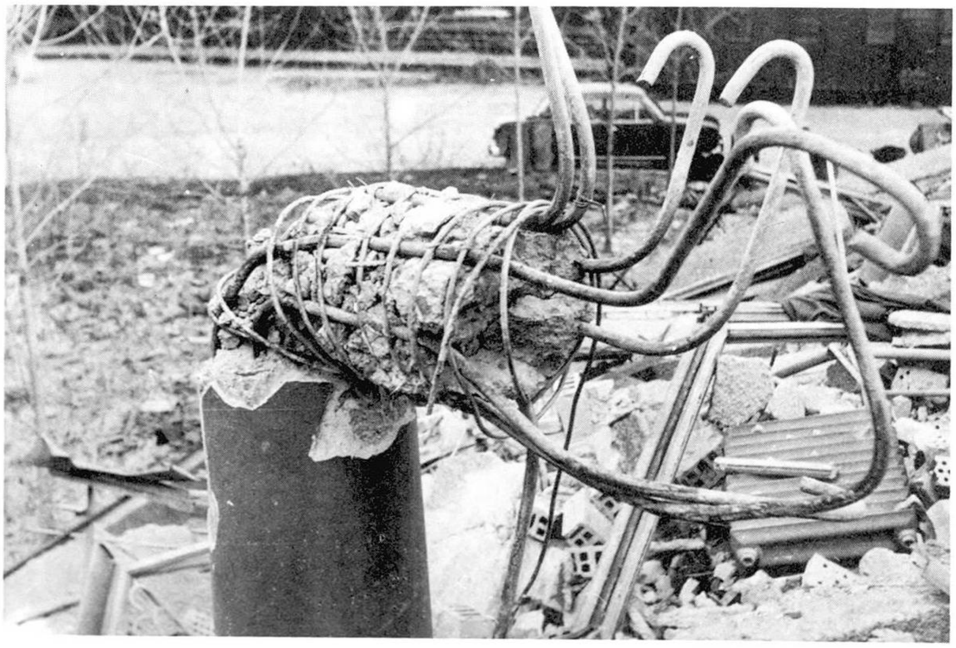

fig. 12

fig. 13

fig. 14

fig. 15

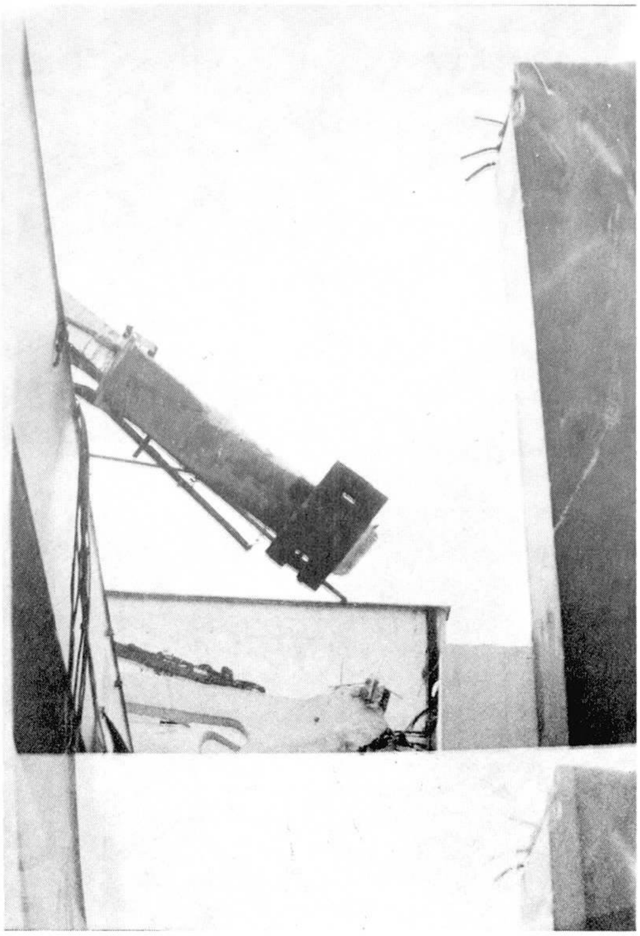

fig. 16