ACCELERATION AND VELOCITY DISTRIBUTION OF THE VRANCEA, MARCH 4, 1977 EARTHQUAKE DETERMINED BY THE RESPONSE OF THE RIGID BODIES

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ABSTRACT

Presented in this paper are ground accelerations and velocities as well as the seismic intensity degree during the March 4, 1977 earthquake at Vrancea in Romania, and the relationships between ground accelerations and velocities and the seismic intensity degree.

Ground acceleration and velocities were determined from data on rigid body response due to the earthquake, while the seismic intensity was defined according to destruction manifestations caused by the earthquake

GENERAL DATA ON THE EARTHQUAKE AND THE INVESTIGATED DATA

The March 4, 1977 earthquake, which occured in Vrancea region at the depth of 95 km, and had a magnitude of 7.2. It caused severe damage to a large part of the area of SR Romania. 1570 people were killed and more than 11300 people were injured. The earthquake caused heavy damage to 32900 flats, as well as school buildings, hospitals, cultural institutions, office buildings, industrial halls, agricultural and traffic facilities, historic monuments, technological plants and so on. Total losses caused by the earthquake exceeded 2 billion dollars.

The major destruction manifestations were observed within the area of the outer Carpate arch, which includes the Moldavian plateau, in the north, Dobrudza, in the east, and the Romanian valley, in south and south-east. The ground surface layers of this area of miopliocene and quarternary sediments of sands and gravels, and mainly of marlstones and clays, which due to their uniform structure differ mostly according to their thickness.

The investigation area, with major destruction manifestations and damages studied to investigate the earthquake effect, comprises 1/3 of the whole territory of Romania. To compile information on rigid objects response to the earthquake and damages, study visits were paid to 19 more important towns, mostly administrative centers of provinces, and five characteristic zones in Bucharest.

EARTHQUAKE EFFECT INTENSITY

According to the destuction manifestations and based upon the MSK-64 scale criteria for earthquake effect intensity evaluation by damage degree to structures, an intensity of 7 to 8 degree was determined in the investigated area. The highest intensity was observed at Craiova ($+8^{o}$), and the slighest one at Constanta and Turn Severin (6.5^{o}). The seismic degrees of the earthquake effect intensity, as observed at the investigated towns and urban zones of Bucharest, are demonstrated in Figs. 1a and 1b, as well as in the Table in which only the towns and zones in Bucharest from which data on the response of rigid objects were collected have been listed.

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GROUND ACCELERATION AND VELOCITY

To define ground accelerations and velocities, about 300 data on response of rigid objects, mostly tombstones at city cementaries of 14 towns and 5 zones in Bucharest were collected immediately after the earthquake.

Ground acceleration was determined by the conditions of sliding and overturning of rigid objects Fig. 2 subjected to the earthquake approximated in terms of triangular, sinusoidal or rectangular impuls. The amplitudes of the impulses denoted horizontal ground acceleration (α_h) in terms of coefficient (K_h) of the ground acceleration (g); and the adopted time duration of the impulse action (τ) of 0.60 sec according to the semi-period of peak acceleration of the horizontal ground acceleration as recorded at INCERK in Bucharest, Fig. 3.

The real values of the ground acceleration were obtained for the effect of a rectangular impulse. For the horizontal ground acceleration coefficient (K_h), the expression (1) is obtained from the object sliding condition, and expression (2) from the object overturning condition.

$$\frac{D}{g\tau^2} = \frac{K_h\left[K_h(1+rF_d)-F_d\right]}{2F_d(1-rK_h)} \qquad ...(1)$$

$$K_h = \frac{A}{2}(1+1+B_o) \qquad ...(2)$$

$$A = \text{arc tg}\,\frac{b}{h} \quad p = (WR/I_o)^{\frac{1}{2}}$$

$$r = \alpha_v/\alpha_h \qquad F_d = 0.8\,F_s \qquad B_o = 2(\cos hp\tau - 1)^{-1}$$

The terms D, α_h and α_v, and F_d and F_s, in expression (1) denote object displacement, horizontal and vertical ground acceleration, the relation of horizontal and vertical acceleration, which is in our case taken to be 0.50, dynamic coefficient of friction of the object and the base, and statical coefficient, which according to the collected data on sliding of objects is determined to be 0.40, respectively, while the terms b and h, R, W and I_o in expression (2) stand for the state and radius of rotation of the object mass center around the overturning point, weight and moment of inertia of the object, respectively.

Ground velocity is determined by analysis of the energy required to cause sliding of the object, and for velocity of the horizontal movement of the object (V_h) the expression (3) yields the following form:

$$V_h = 0.71\,(Dg/Bq)^{\frac{1}{2}} \qquad ...(3)$$

where D, B and q are ground displacement, dynamic coefficient of ground response and vertical and horizontal ground velocity relationship, respectively. In our case, Bq is taken to be 2.

Applying the expression (1), (2) and (3), based upon the data on response of rigid objects, the individual values of ground accelerations and velocities were calculated, from which the corresponding historgams were defined which were further used to determine the dominant ground accelerations and velocities in each of the considered towns and the zones in Bucharest. The coefficient of the upper ground acceleration level (K_u) and the coefficient of the lower ground acceleration level (K_l) for overturning of rigid objects was determined from the data on their sliding. The obtained predominant values of the acceleration coefficient (K_u and K_l) and the ground velocity for the considered towns and zones in Bucharest are presented in the Table together with the evaluated degree of the earthquake effect intensity (I) in them.

Towns and zones in Bucharest	Intensity I (MSK-64)	Acceleration $K_{upper(g)}$	Coefficient $K_{lower(g)}$	Velocity V (cm/sec)
1. Craiova	+8	0.318	0.207	33.07
2. Zimnicea	8	0.301	0.213	42.74
3. Birlad	8	-	0.211	-
4. Bukuresti	8	0.321	0.199	30.80
5. Iasi	-8	0.303	0.263	29.94
6. Foksani	-8	0.301	0.184	31.68
7. Ploesti	-8	-	0.230	-
8. Turnu Magurele	-8	-	0.172	-
9. Alexandria	7.5	0.284	0.190	23.30
10. Galati	+7	0.285	-	23.55
11. Tirgoviste	7	-	0.165	-
12. Pitesti	7	-	0.164	11.38
13. Slatina	7	-	0.161	-
14. Konstanta	6.5	-	-	18.01
Bucharest				
A. Town centre	8	0.322	0.192	30.80
B. Cim. Belu	-8	0.320	0.202	30.80
C. Cim. Grivitea	7.5	-	0.192	-
D. Cim. Tacerii	7.5	-	0.213	-
E. Cim. Ghencea	7	-	0.187	-
F. Cim. Ermen	7	-	0.188	-

RELATIONSHIP BETWEEN GROUND ACCELERATIONS AND VELOCITIES AND SEISMIC INTENSITY DEGREE

The ratios of the acceleration coefficients (K_u and K_l) and ground velocities (V) with the seismic intensity degree are given in Figures 4 and 5. The values obtained for the towns are marked with dots, those obtained for zones in Bucharest are marked with crosses. The values marked with circles represent the predominant ground accelerations and velocities for areas with equal seismic intensities, obtained by summarized histograms of individual values of ground accelerations and velocities. Based upon the figures useful conclusions on the relationship between ground accelerations and velocities, and the seismic intensity degree defined according to the seismological scales of the Merkali type can be drawn.

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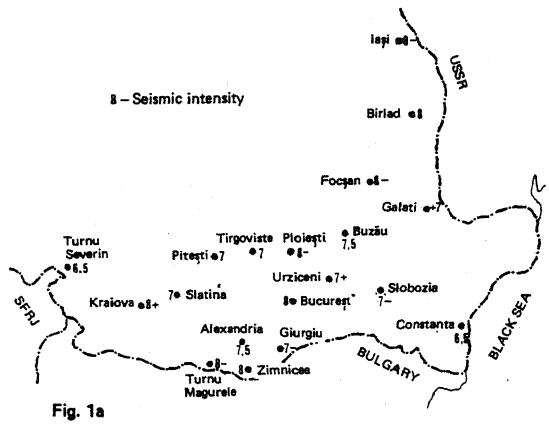

Fig. 1a

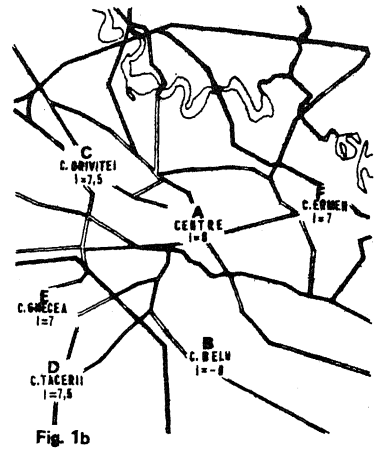

Fig. 1b

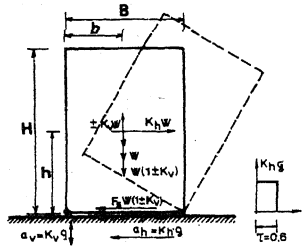

Fig. 2

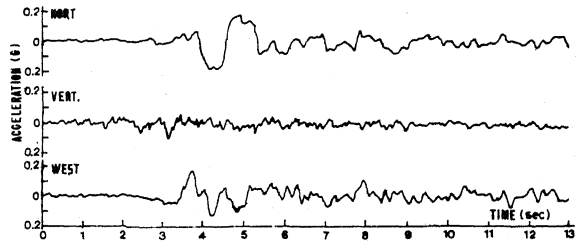

Fig. 3

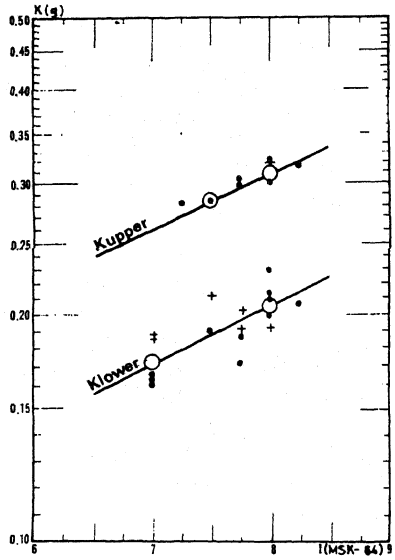

Fig. 4

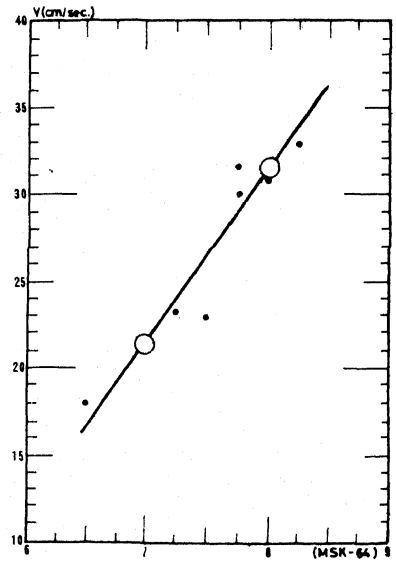

Fig. 5