Wave effects induced in the Romanian Plain and seismic macrozonation

ROMANYA PLATOSUNDA ORTAYA ÇIKAN DALGA YAYILMA ETKİLERİ VE MAKROBÖLGELEME

Ş. Mişicu[1], M. Mişicu[2], Gh. Mărmureanu[3], E. Cojocaru[4]

ABSTRACT

In view of a generalizėd characterization of directivity of mechanical waves linked with a qualitative analysis involving special features of these dynamic processes, we present graphic representations with isoseistic lines obtained via Green functions and illustrate them with the seismic effects of the Romanian plain. These elements leads to a subsequent procedure of qualitative analysis of directivity.

1. The Green functions of the field induced for a double-couple dislocation.

The Green functions for dislocation fields were firstly analysed by E.Kröner[6]. Here on the basis of equivalent body forces f which induce the same effects as a double-couple dislocation at a point $x = 0$ there is also considered the displacement field in a medium with a density ρ and Lamé coefficients λ, μ. The initial boundary condition is $\mathbf{u} = 0$, $(t < 0)$ and the corresponding wave equation takes the form

$$\rho\ddot{\mathbf{u}} - (\lambda + \mu)\nabla(\nabla\mathbf{u}) - \mu\Delta\mathbf{u} = \mathbf{f}\delta(t)\delta(x) \tag{1}$$

The solution is yielded under the form

$$\mathbf{u}(t, x) = G(t, x)\mathbf{f} \tag{2}$$

where G stands for the Green function[6]

$$G_{ij}(t, x) = \frac{\gamma_i\gamma_j}{4\pi\rho\alpha^2}\cdot\frac{\delta(t - r/\alpha)}{r} + \frac{\delta_{ij} - \gamma_i\gamma_j}{4\pi\rho\beta^2}\cdot\frac{\delta(t - r/\beta)}{r} + \frac{1}{4\pi\beta}(\frac{t}{r})_{,ij}H(r, r/\alpha, r/\beta) \tag{3}$$

Here occur the following quantities: $\alpha = (\lambda + 2\mu)/\rho$, $\beta = \mu/\rho$, (the velocity of P and S waves), $r = |x|$, $\gamma_i = X_i/r$ and H the "box-car" function $H(t, a, b) = 1$ for $a < t < b, = 0$ in the remaining time interval. The last term corresponds to the

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[1] Sci.Res.,Nat.Inst.Earthphys.,Bucharest,Romania
[2] Sen.Res.,Nat.Inst.Earthphys.,Bucharest,Romania
[3] Sen.Res.,Nat.Inst.Earthphys.,Bucharest,Romania
[4] III-Deg.Res.,Nat.Inst.Earthphys.,Bucharest,Romania

near field which will be subsequently disregarded.

2.Determination of wave amplitudes for the far field in terms of seismic magnitudes.

According to previous analysis published in [4,5], the displacement components induced by a dislocation located at the point $X = 0$ on the intersection between a vertical plane which includes the X_1-axis and a plane with slope Δ are given by the following relations

$$u_i = \frac{M\mathcal{F}_i}{4\pi\beta r} \tag{4}$$

for

$$\mathcal{F}_1 = \gamma_3(1-2\gamma_1^2)\cos 2\Delta - \gamma_1(1-\gamma_2^2+\gamma_3^2)\sin 2\Delta \tag{5}$$

$$\mathcal{F}_2 = \gamma_2(\gamma_2^2-\gamma_3^2)\sin 2\Delta - 2\gamma_1\gamma_2\gamma_3\cos 2\Delta \tag{6}$$

$$\mathcal{F}_3 = \gamma_1(1-2\gamma_3^2)\sin 2\Delta + \gamma_3(1+\gamma_2^2-\gamma_3^2)\sin 2\Delta \tag{7}$$

where M stands for the earthquake kinematic magnitude.
Meanwhile the arrival times of the front waves are given by the relation $t = r/\beta$. These elements enable us to characterize the seismic effects induced in a choosen region through isoseistic lines ($u_i = const.$) in the frame of synthetic diagrams. The advantage of such description consists in the emphasising both relevant data. Based on these data we are able to sketch a first characterization of directivity of front waves leading to a subsequent qualitative analysis.
In the case of the Romanian Plain the seismic events are mainly concentrated in discrete sources to which may be added secondary continous sources.
The reflection and refraction effects will also be subsequently determined on the basis of her presented results.
The illustrative elements are based on the data for the *4 march 1977* earthquake belonging to a kind of events of maximal consequence for the considered region for 3 sources ($S_1; S_2; S_3$), depths (km: 79, 93, 109), latitude (degrees: 45.72; 45.48; 45.34), longitudes (degrees: 26.94; 26.78; 26.60), magnitude (6.5; 6.5; 7.2), time intervals from the fore shock in seconds (4.7; 12.3; 19.2), kinematic magnitude in cm^3($0.339{\cdot}10^{15}; 0.339\cdot 10^{15}; 2.84\cdot 10^{15}$), orientation of dislocational plane in degrees ($40^\circ N - E$), slope of dislocational plane $\Delta = 70^\circ$, velocity of transversal waves ($\beta = 4.7 km/sec$, density $\rho = 3.2 t/m^3$ upper level (under the Earth surface): 8.9 km.
The obtained results show a good agreement with observed data despite the fact that secondary perturbations were disregarded(attenuation, curvature of rays).
We have also performed the calculation of the accelerations a_i starting from the observation that the pulse which characterize the source are defined by a time interval T and a period $2\pi/T$(see ref.[3]) so that $a \simeq -\omega^2 u_i$.
The orientations of the choosen X_1-axis is $40^\circ N - E$. The X_2-axis is orthogonal to the previous one and also horizontal. The X_3-axis is vertical. The origin is the S_1 source.

The diagrams 1 – 4 emphasize features which involve clearely consequences of real interest. The contour lines associated with the induced displacement at the top of ground rock are ploted in the first quarter for $X\ :\ 0\ -\ 200km$ and $Y\ :\ 0\ -\ 200km$, because this region is relevant for the microzoning in the Romanian Plain. For instance the displacement in transversal sense u_1 given in Figure 1 (orthogonal to the intersection line of dislocational plane with the Earth surface) are the more important ones and are much more large on a single side of the mentioned line, fact which increases the seismic effect in the considered region. We point out that for an orientation of dislocation which differs from the direction of the slope line of dislocational plane, the effects are far more increased in the same region [2]. Meanwhile the directivity effects are extended mainly in a single direction(corresponding to the above mentioned line) and decay more rapidly in the orthogonal direction. If we consider the distances d from the epicentral point till to a point located on an isoseistic line and calculating the ratios $q = d_{max}/d_{min}$ corresponding to points of the same isoseistic line, we obtain a characteristis measure of geometric nature. This ratio is for the displacement u_1 close to the value 3 in the considered region, which implicitely appears as strongly influenced. The source S_3 which acts as the last one is the closest one to that mentioned above and also the strongest one. This fact involve a general increased effect, the shocks of all sources being closer in time and occuring in an enhanced manner.

The displacement (see Figure 2) u_2, is characterized by 4 lobes separated by the orthogonal lines mentioned above (where the displacements may vanish) and with increasing values in the sense of bisectorial lines of the angles defined by the other ones. The ratio q is smaller (≤ 2) and the intensity of respective amplitudes of the displacement u_1 (approximately 10

The vertical displacements, exhibited in Figure 3, present a strong concentration around the epicenter and 3 lobes. The variation of amplitudes is important and may present vanishing zones enough close to the epicenter where appear values with alternate signs. The ratio q may reach the value 3, but due to the necking character of isoseistic lines, at great distances this ratio increases sensibly. The amplitudes are approximately twice times larger than for u_2.

We have also computed the total displacement

$$U(S_3) = \sqrt{u_1^2 + u_2^2 + u_3^2} \tag{8}$$

and ploted it in Figure 3. It is worthwile to note that the shape of $U(S_3)$ is very close to that of u_1. This was to be expected since we made earlier the observation that the horizontal displacements u_1 are much stronger than the other two.

The exposed features do not stand for a complete characterization of the directivity effects. Additional measures will be analysed on the basis of combined isochronic and isoseistic graphics.

A last observation concerns the variation of seismic effects at different depths. We observed in a previous paper that starting from a distance of $40km$ from epicenter for the displacements $u_1(S_1)$ and $80km$ for the displacement $u_1(S_3)$, the values vary slowly from the surface level till a depths of $20km$.

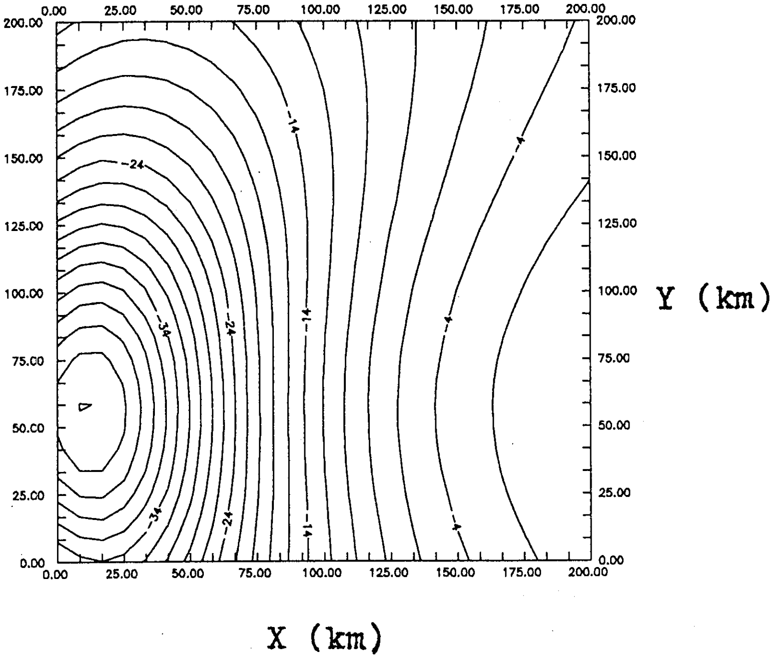

Figure 1

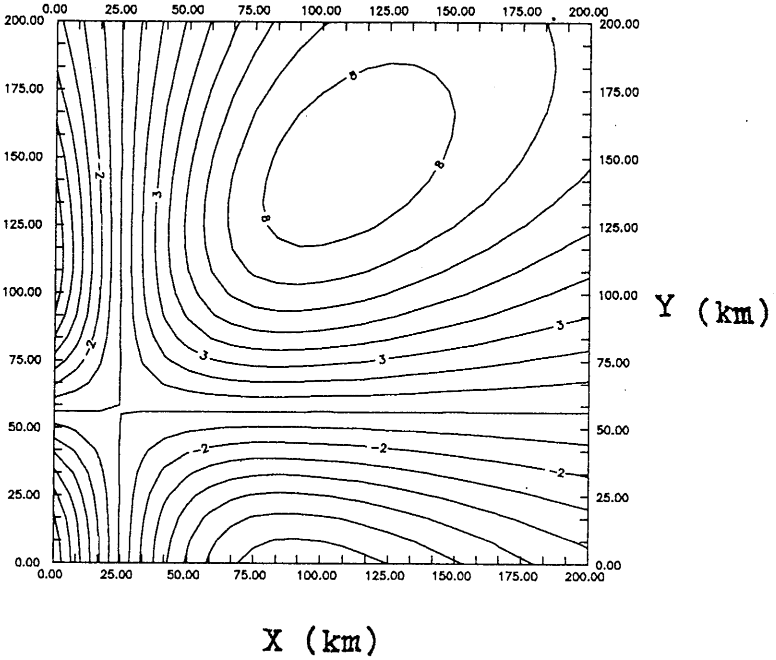

Figure 2

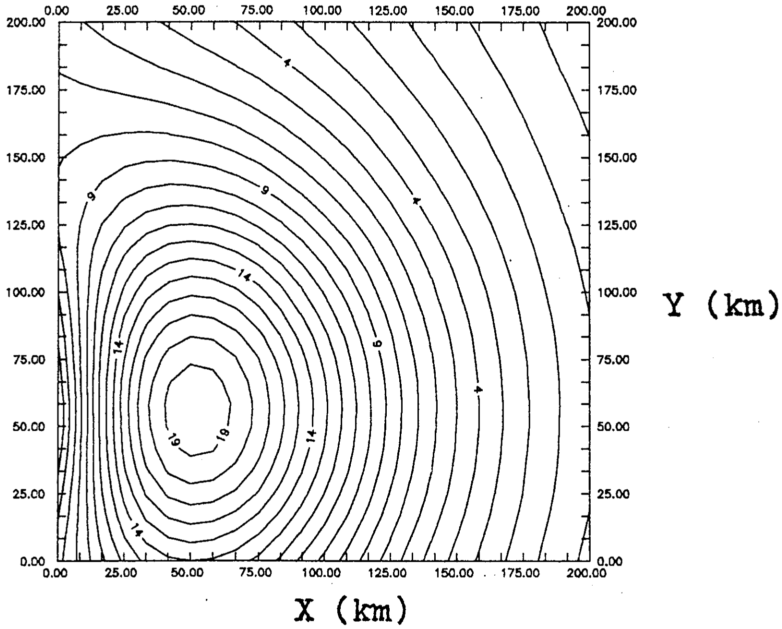

Figure 3

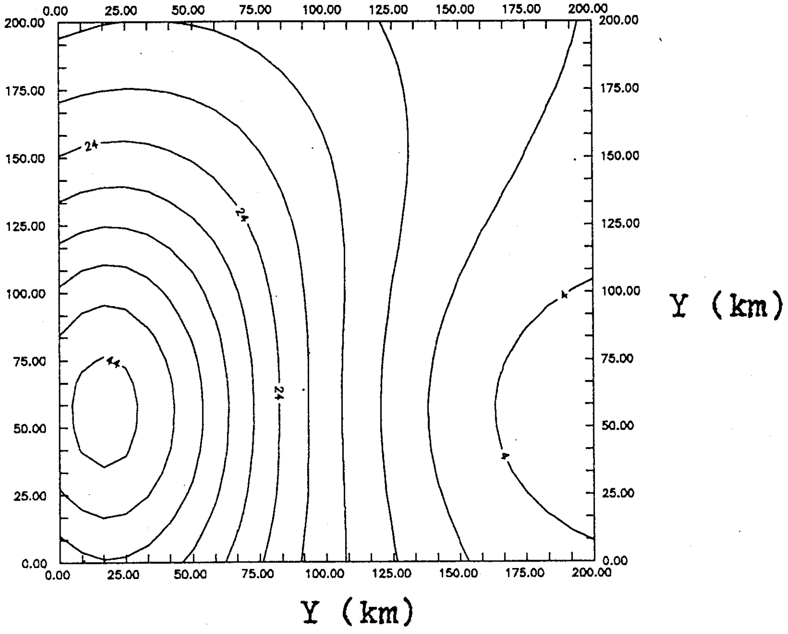

Figure 4

Table 1: Displacements and accelerations induced by the source S_3 at characteristic points of Romanian Plain

Region	Cricov	Bucharest	Călugareni
$u_1(S_3)(cm)$	30.94	22.10	17.68
$u_2(S_3)(cm)$	8.70	6.62	4.42
$u_3(S_3)(cm)$	6.64	10.00	8.84
$a_1(S_3)(g)$	0.31	0.22	0.18
$a_2(S_3)(g)$	0.09	0.06	0.1
$a_3(S_3)(g)$	0.18	0.04	0.08

Table 2: Coordinates refered to the sources S_1, S_2, S_3

Region	Cricov	Bucharest	Călugareni
$X_1(S_1)(km)$	13.49	39.38	63.8
$X_2(S_1)(km)$	91.27	158.42	178.57
$X_1(S_2)(km)$	6.14	32.29	56.71
$X_2(S_2)(km)$	59.27	126.42	146.57
$X_1(S_3)(km)$	25.3	51.19	75.61
$X_2(S_3)(km)$	35.27	102.42	122.57

In the subsequent Table 1 appear the principal values of displacements and accelerations at three points of Romanian Plain. These points are defined by the coordinate systems referd at the source S_1 from Table 2.

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