A COUPLED RESPONSE OF EXPLOSIVE ENERGY AND ITS IMPLICATIONS TO SEISMIC RISK IN VARIOUS MEDIA

BY

A.Grover[I]

SYNOPSIS

The effect of medium immediately surrounding the explosive source on the properties of the primary compressional waves has been studied by means of three dimensional model. An approximate theory for radiation from a single harmonic line source of P-waves on the axis of the solid circular embedded in an infinite homogeneous solid medium has been developed. The results obtained in both time and frequency domain are greatly dependent on the characteristics of the medium around explosion. A varying degree of seismic risk is evaluated with the size of the cavity radius and medium surrounding the source.

INTRODUCTION

An impact of characteristics of the medium surrounding the source on seismic risk has been considered by few investigators in the past. A review of physical properties of the medium has been made in relation to the change of dynamic parameters, both with the aid of observed data and theoretical analysis. We studied some of the parameters such as coupling and source function by means of laboratory three dimensional models.

EXPERIMENTAL PROCEDURE

The basic three dimensional model was comprised of cubic-block of Plaster of Paris, 30 cm. on an edge. Explosive charges were cast in a spherical capsule, weighing 100mgm each. The charge was centered in each experiment and the spherical symmetry of source was maintained by overcoming a few of the factors such as moisture. The signal from an explosion was detected by capacitance probes, amplified and displayed on an oscilloscope for recording. The block model was shielded with aluminium foil so that no electrical transients are picked up. The experiments were carried with explosive cavity around the charge of radii, a, 1). 0.31cm 2). 0.79cm 3). 2.54cm. Except a=0.31cm which was contained shot, other two were surrounded by air and sand respectively. The seismograms, Figure 2, show the vertical component of motion from a) contained shot, b) shot in air cavity, a=.79cm, c) shot in sand filled cavity, a=.79cm, d) shot in air cavity, a=2.54cm, e) shot in sand filled cavity, a=2.54cm, The velocities of P-wave in sand and Plaster of Paris were measured to be 0.28km/sec and 3.3km/sec respectively. The vertical timing lines were 50microsec apart on each record. The oscilloscope sensitivity used is indicated at the right of each record.

OBSERVATIONS AND THEORY

An examination of seismograms obtained from sand filled-

[I] Research Geophysicist, formerly at St. Louis University, St.Louis.

cavities, Figure 2c and 2e, revealed only small variations in amplitude and a steady increase in the period of first half-cycle of the primary P-wave for increasing value of the cavity radius.

The Sharp-Blake(1952) theory is applied in interpreting the data. The displacement for a single harmonic line source of P waves on the axis of the solid medium is determined to be

$$\frac{U_r}{U_i} = \frac{2\omega^2 \rho_1 \sqrt{1+\frac{a^2\omega^2}{\alpha_2^2}}}{\alpha_1 \sqrt{1+\frac{a^2\omega^2}{\alpha_1^2}\left[\frac{\omega^2}{a^2}\left\{(\rho_1-\rho_2)-\frac{4}{\alpha_1\alpha_2}(\mu_1-\mu_2)\right\}^2+\frac{\omega^2}{a^2}\left(\frac{\rho_1}{\alpha_2}+\frac{\rho_2}{\alpha_1}\right)\right.}}$$

where

a=cavity radius

$\omega = 2\pi f$

α_1, ρ_1, μ_1 and α_2, ρ_2, μ_2 are P-wave velocity, density and rigidity two media respectively.

The response function was, T, calculated with a=.31, .79, 1.27, 1.91, and 2.54cm; α_1 =.70km/sec, ρ_1 =1.1gm/cc^3 for sand; α_2 =3.3km/sec, ρ_2 =1.5gm/cc^3 for Plaster of Paris. The plot is shown in Figure 1. The theoretical result from Figure 1 is that the geometric effect of shooting in a spherical cavity is to shift the spectrum of the outgoing wave towards lower frequencies. The peak value of response function is independent of cavity radius.

The peak radial stress transmitted to the medium according to Nicholls and Duval(1963) is equal to $(1+n)P_D/(1+nR)$ where n=constant=5, R=ratio of characteristic impedance of explosion and medium. In our experiments the peak radial stress in the medium was calculated as 9.2 kilobars.

The equivalent cavity radius is calculated according to the formula given by Blake(1952):

$$b = \frac{\alpha\tau\sqrt{m+m^2}}{\pi(1+2m)}$$

where

$m = \frac{\mu}{\rho}$

τ= period of pulse

The results of equivalent cavity radius are illustrated in Table1. For sand-filled the radius of equivalent cavity is smaller than the cavity radius, a, (i.e.b a) wheras in air this is not the case.

FREQUENCY SPECTRA

The fourier primary wave spectra of the five seismograms are shown in Figure 3. Figure3a shows the amplitude spectrum of a coupled shot in Plaster of Paris. The dominant frequency of P-wave is about 20KHZ.

The effect of replacing air by sand in a cavity of radius 0.79cm on the frequency content and amplitude of the P-wave can be examined by comparing the spectra of Figures 3b and3c. For sand,the peak amplitude is about twice that in air wheras the dominant frequency is reduced by a factor of nearly two.

The fourier spectra in Figures 3d and3e are shownfor a shot in a cavity of radius 2.54cm surrounded by air and sand respectively. The peak amplitude in sand is almost ten times as large as in air wheras the dominant frequency is half its value in air.

The decoupling effect of shooting in air and the increased coupling obtained insand filled cavities are demonstrated in Figure 4, which shows the spectra for air and sand cavities when all the amplitudes are normalized to the spectrum of a coupled shot. Figure 4B shows an amplitude minima at 30KHZ for sand-filled cavity of radius 0.79cm, wheras Figure 4D does not show the sharp minima for sand-filled cavity of radius 2.54cm.

The P-wave spectrum can be significantly altered by surrounding the source with a material with properties different from those of the principal medium in which the signal is recorded. Even for small cavities the inhomogeneity is effective, as long as the cavity is big enough so that not all of the material in it is involved in the nonelastic region around the explosion. The low velocity medium surrounding the source such as sand may significantly alter the character of the P-wave by considerable enhancement of the lower frequency part of the amplitude spectrum.

ACKNOWLEDGEMENT

A part of this research and experiments were performed at the Department of Earth Sciences, Saint Louis University,St. Louis, Missouri,U.S.A.

REFERENCES

1. D.S.Bahjat and C.Kisslinger: Coupling of Explosive Energy in Three Dimensional Models; Geophysics 35(1970),213.
2. F.G.Blake: Spherical Wave Propagation in Solid Media; Jour. Acoust.Soc.Amer. 24(1952) 211.
3. W.M.Ewing,W.S.Jardetzky andF.Press: Elastic Waves in Layered Media; McGraw Hill (1957), New York.
4. H.R.Nicholls and W.L.Duvall: Effect of Characteristic Impedance on Explosion-Generated Strain Pulses in Rock; Fifth Rock-Mechanics Symposium, University of Minnesota, Fairhurst Editor Pergamon Press (1963).
5. V.Schenk: Parameters of Stress Waves Produced by a Spherical Explosive Source; Fifth World Conference on Earthquake-Engineering (1974) Rome.

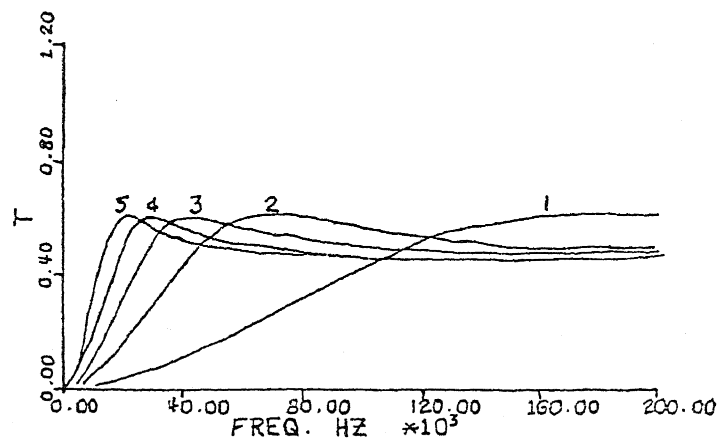
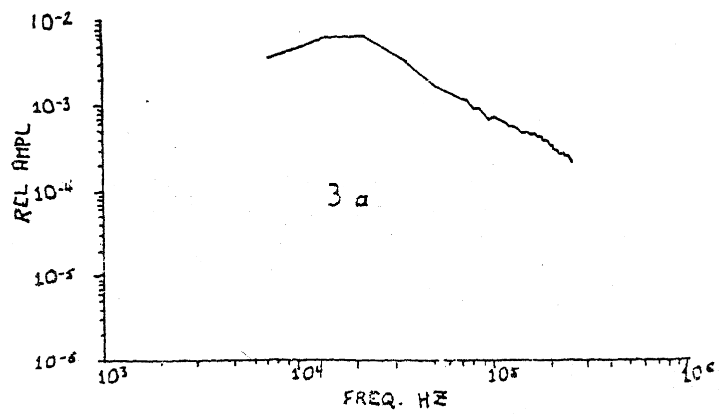


FIGURE 1. Response Function



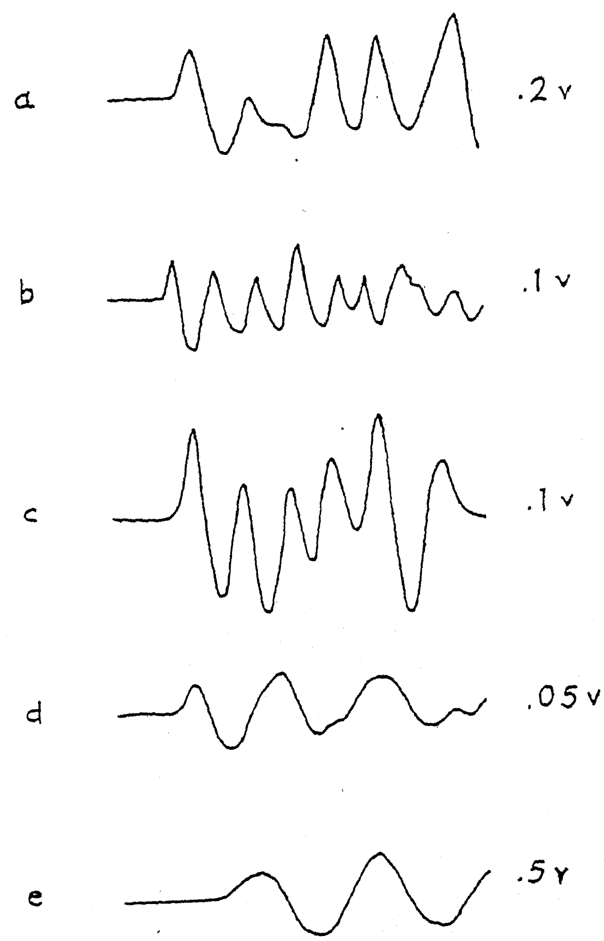
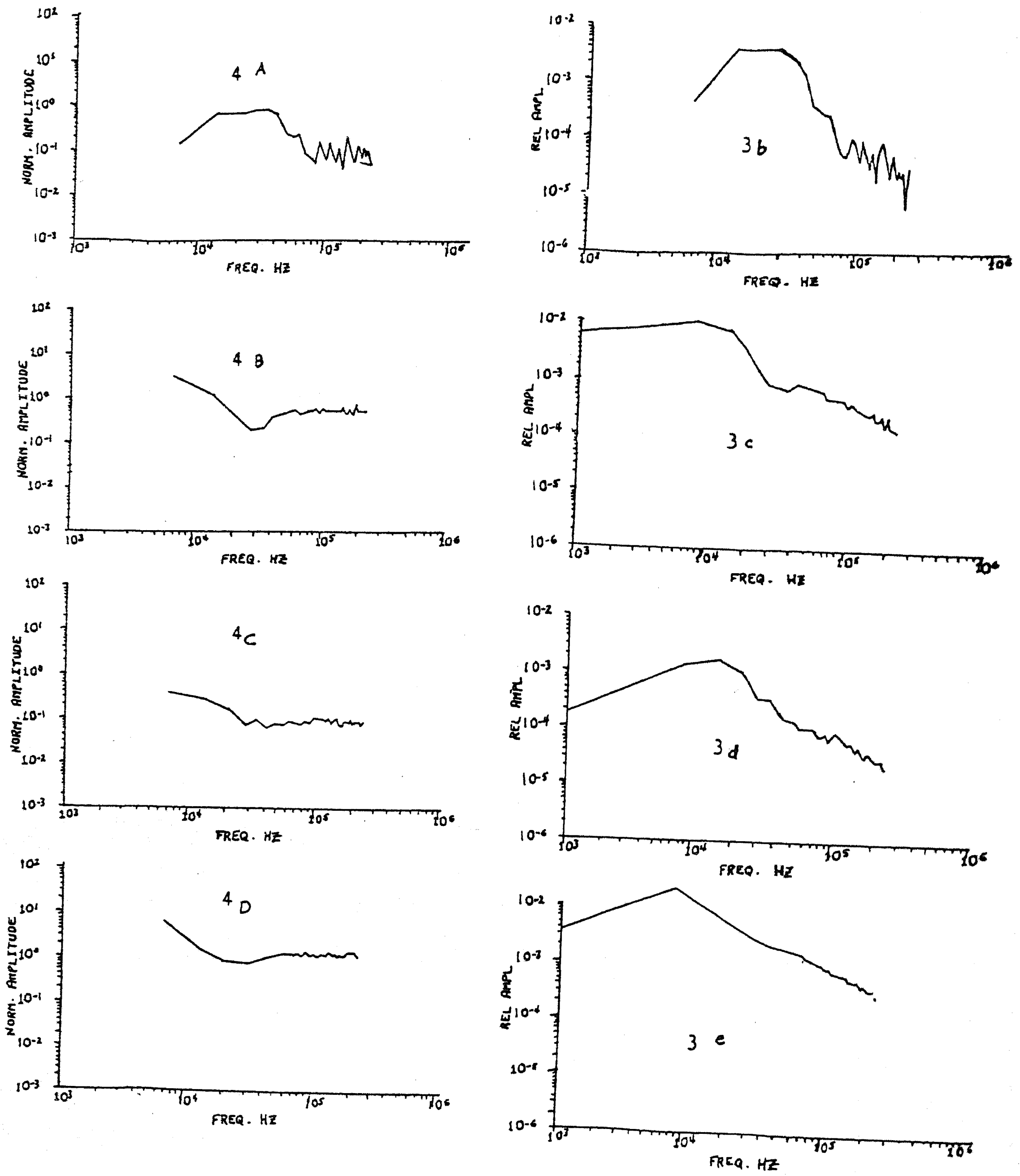


FIGURE 2. Seismogram records for a)0.31cm b)0.79cm with air c)0.79cm with sand d)2.54cm,with air e)with sand.

TABLE 1

Record Number	Cavity Radius a	Pulse Width τ	Equivalent Cavity Radius b	Medium
a.	0.31cm	37microsec.	3.6cm	Plasterof Paris
b.	0.79cm	25 "	2.4cm	Air cavity
c.	0.79cm	40 "	0.65cm	Sand cavity
d.	2.54cm	39 "	3.8cm	Air cavity
e.	2.54cm	79 "	1.3cm	Sand cavity


4 A
NORM. AMPLITUDE
FREQ. HZ
3 b
REL AMPL
FREQ. HZ
4 B
NORM. AMPLITUDE
FREQ. HZ
3 c
REL AMPL
FREQ. HZ
4 C
NORM. AMPLITUDE
FREQ. HZ
3 d
REL AMPL
FREQ. HZ
4 D
NORM. AMPLITUDE
FREQ. HZ
3 e
REL AMPL
FREQ. HZ