An analysis of shock waves generated by fireworks

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High speed objects such as jet planes, space shuttles, and meteorites generate shock waves in the atmosphere. It has been known that the shock waves cause ground motions which can be detected by seismographs (e.g. Nagasawa and Miura, 1987; Brown et al.,2002). However, the response of the ground to the air shock waves is little understood. The purpose of this study is to obtain a relation between the pressure of a shock wave and the amplitude of the induced ground motion. We observe shock waves from fireworks and the ground displacements. Experiments are performed twice. In the first experiment, the ground notions are observed by a seismograph (L22D) installed at a depth of 0.4m beneath the epicenter of the firework explosion. The pressures of the shock waves are monitored by a blast meter (PMS5) at a height of 0.8m with a separation of 50m from the seismograph. The digital signals are recorded with a sampling frequency of 1kHz. In the second experiment, the configuration of the observing system is the same as the first case excluding the sampling frequency of 10kHz. We use only signals whose frequencies are smaller than 100Hz, since the response of the seismograph is found to be unstable in a frequency higher than 100Hz.

The relation between the observed amplitude B (Pa) in the initial wave of the pressure and the ground displacement A (m) is given as follows.

$A = (5x10)B$ (1)

This relation can be interpreted as

$A = E\ k\ B$ (2)

where E is a representative elastic constant and k is the wave number of the elastic wave generated in the ground. Vp at the observation point is measured to be 300m/s. Vs is assumed to be about several ten meters per second. Then the elastic constant E is supposed to be a value similar to Young modulus.

The observed period of the ground displacement is generally 1.3 times longer than that of the pressure. It is likely that there is a frequency dependence of the ground response to the shock wave. We determine also a relation between the powder charge Y (kg) and the frequency T (s) of the ground displacement. It is given as follows.

$\log Y = 2.7 \log T + 4.7$ (3)

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