Vibration of the Ground, especially of the Superficial Soil Layers

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SYNOPSIS

Studies were made, 1) of the vibrational characteristics, especially, of the superficial soil layers, basing mainly on the observations of artificial and natural earthquakes; and 2) of these characteristics of a combined system consisted of the ground and structure.

The rusults of our study are as follows:

1) In the micro-tremors observed on the ground surface, the vibrations of two or three layers lying very near the ground surface are remarkable.

2) As for the ground vibration caused by artificial earthquake, it is obvious that the predominant period of vibration of the ground becomes longer as the energy-release at the source of vibration becomes larger.

3) With regards to the vibration of the building standing on the soft ground, a similar tendency as above may be seen, that is, the natural period of the building may be lengthened as the vibrational energy of the surface layer becomes larger.

EXPERIMENT AND RESULT

1. Micro-tremors

As well-known, the micro-tremors are a set of inherent vibrations of various soil layers, and may vary according to the nature of superficial soil layers. (Fig. 1) These tremors can be interpretted as a result of the multiple reflections of the incident shear waves on these layers. In this interpretation, a model of the stratified ground is assumed usually in which the layers are N in number. The vibrations of the ground of which structure is shown in Fig. 2 are analysed by the Fourier analysis, and the spectrum curve is constructed, Fig. 3. The peak periods in the Fourier spectrum agree with those in the frequency-response curves determined through the calculation made of the model having a certain number of layers, say, N, N-1, N-2, ..., 1. In our case, N=2 is adopted. In this calculation, the indident waves upon the basal layer are assumed to have uniform spectrum density. The number of layers, N, may be different according to the structure of the ground, but from the results of our measurement made at several places, the number is sufficient to be N=3, in order to fit our calculations with the results of measurements. The fact proves that the micro-tremors are due to the vibrations of two or three superficial layers.

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2. Ground vibrations caused by artificial earthquakes

Three different processes were employed to generate the ground vibrations, i) explosive, ii) shear, iii) air-gun. The soil-condition of the ground where these experiments were made is shown in Fig. 4, and the positions of the origins and the points of measurement are shown in Fig. 5. From the results of vibration tests, it is obvious that the predominant periods of the vibration observed on the ground surface differ according to the process by which the waves are generated. (Fig.6) In other words, the periods relate to the energy-release at the surce of vibration. It may be said that the component-vibrations of a longer period which are included in the microtremors become leading as the input energy becomes larger.

The ground vibrations of the artificial earthquakes may be analysed into two parts, that is, the forced vibrations due to blast and the free vibrations which are the natural vibrations of various soil layers appearing after the forced vibrations. (Fig. 7 and Fig. 8) In the Fourier spectra as shown in Fig. 6, the predominant periods of waves due to various processes are not those of the forced vibrations, but of the free vibrations of the soil layers. If the basal layer is assumed at a deeper place, the soft overlying layer vibrates with a longer period. Such matters may be expected in the case of the natural earthquakes. Therefore, in the treatment of the ground vibration, it is better to pay an attention to determine the proper position of the basal layer which render us possible to obtain any desired period of vibration of the overlying layer.

3. Vibrations of a building standing on a poor ground

From the observations of the earthquakes and other ground vibrations in the underground and in the building standing on a poor ground, it may be said that the vibrations of the building, also of the ground change in the form. It is natural that the energy exhausted in the vibration of the superficial layer becomes larger in amount as the scale of vibration becomes larger. In our case of the ground vibrations concerned, the amount of energy is smallest in the micro-tremors, and largest in the natural earthquakes; intermediately large in the traffic disturbances. The vibrations of the building excited by these three ground vibrations will differ from each other as will be seen in Fig. 9, Fig. 10 and Fig. 11. If the scale of vibration is small as in the case of the micro-tremors, the vibration of the building which is under the condition of base-fixed will be surpressing, but when the scale is large as in the case of the earthquake, the conditions of the building-vibration will be similar to those of the combined system composed of the ground and building, and the component-vibrations of longer period become predominant throughout the ground vibration. In such a case, the natural period of the building is lengthened in some degree. By the way, in the case of a condition base-fixed, the frequency transfer characteristic as shown in Fig. 12 may be recognized.

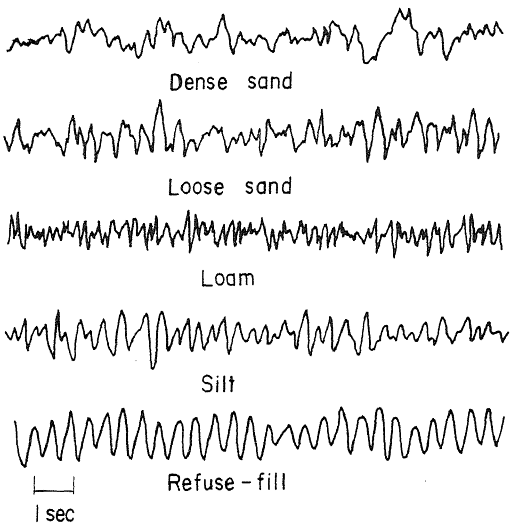

Fig. 1 Specimen records of micro - tremors obtained on the ground of various structures.

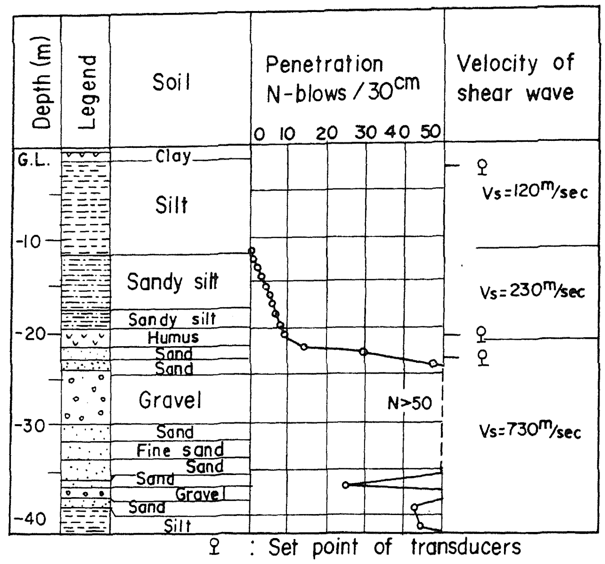

Fig. 2 Subsoil - condition

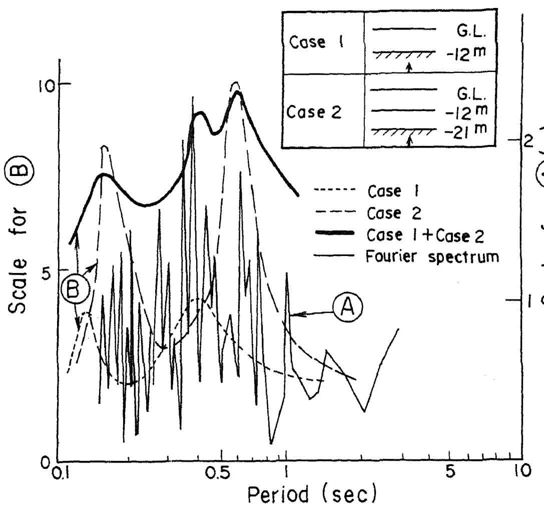

Fig. 3 Frequency-response and Fourier spectrum.

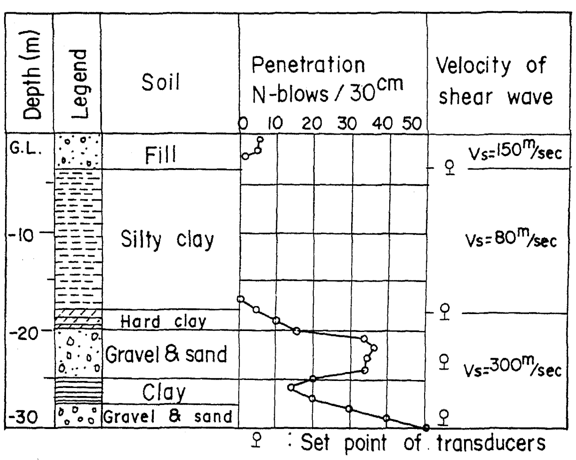

Fig. 4 Subsoil - condition.

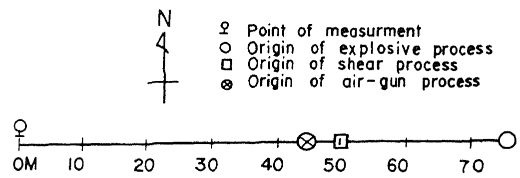

Fig. 5 Origins of artificial earthquakes and point of measurement.

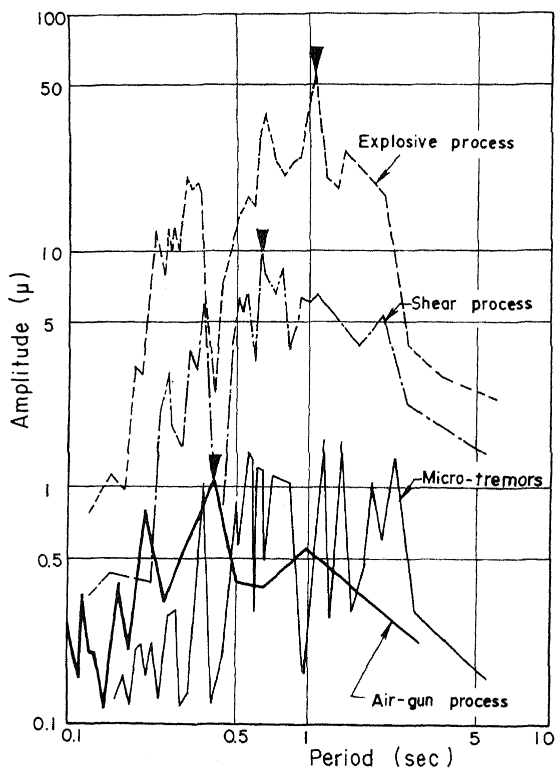

Fig. 6 Fourier spectrum curves for ground vibrations generated by means of different processes.

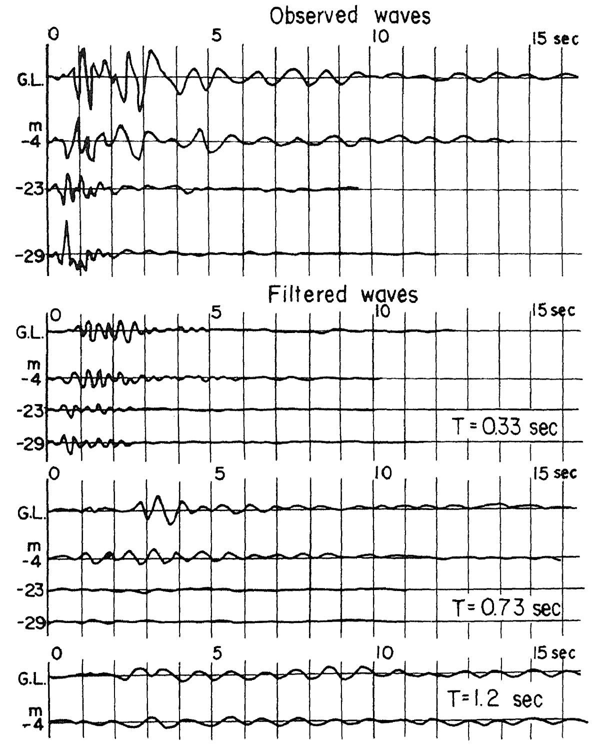

Fig. 7 Observed and filtered waves. (explosive process)

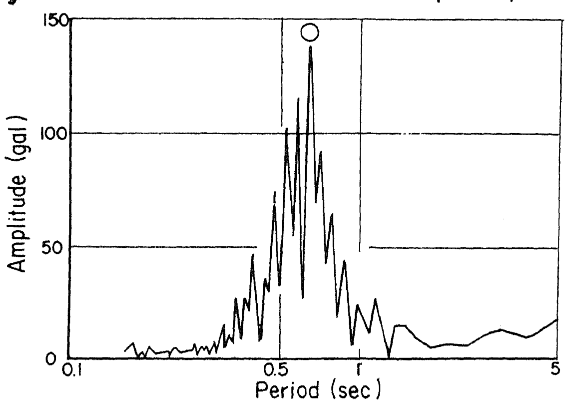

Fig. 11 Fourier spectrum for the earthquake waves obtained at the top of a building.

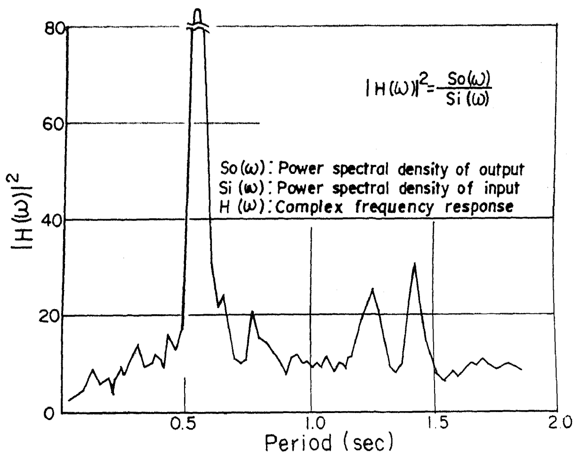

Fig.12 Frequency transfer characteristic.

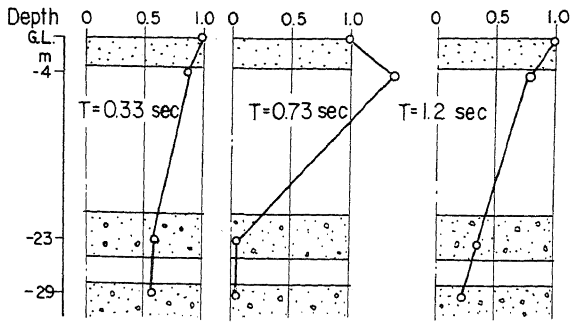

Fig. 8 Vibrational modes of subsoil layers with peak period. (explosive process)

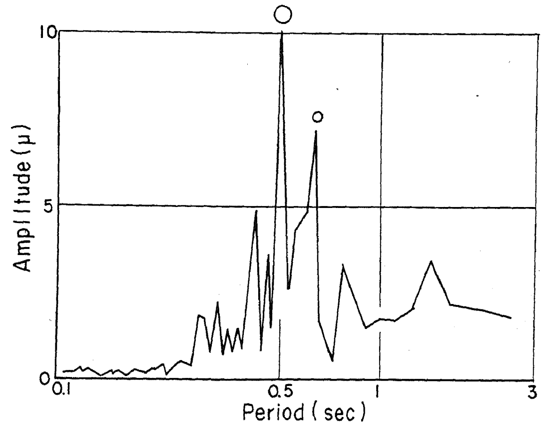

Fig. 9 Fourier spectrum for the micro-tremors at the top of a building.

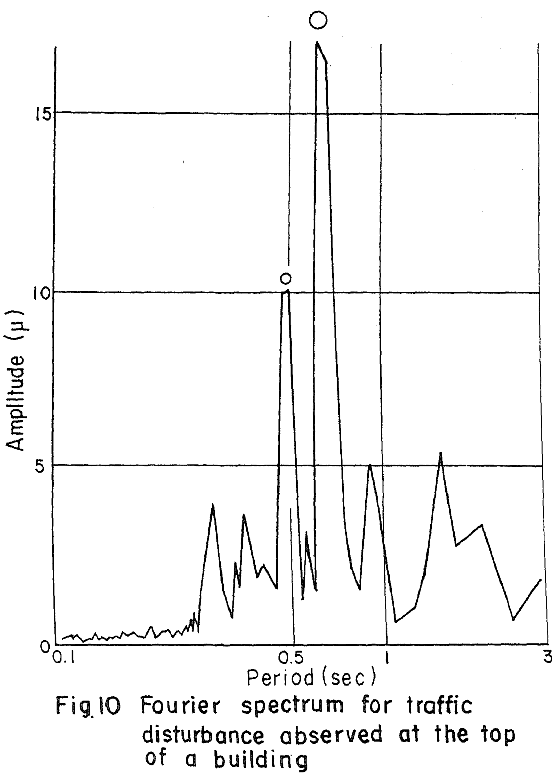

Fig.10 Fourier spectrum for traffic disturbance observed at the top of a building