EFFECTS OF SEISMIC AND SUBSOIL CONDITIONS ON EARTHQUAKE RESPONSE SPECTRA

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SYNOPSIS

Earthquake response spectra have been commonly used to evaluate seismic effects on structures. In this paper characteristics of earthquake response spectra of 44 components of strong-motion records obtained recently in Japan are discussed. Response spectra are classified into several groups in four ways, according to magnitudes, maximum ground accelerations, epicentral distances and subsoil conditions, and consequently the spectra are averaged respectively in each group. From this study the effects of seismic and subsoil conditions on characteristics of earthquake response spectra are evaluated.

INTRODUCTION

The response spectrum technique was first proposed in 1942 by M. A. Biot (1) and it was the clue to development of reasonable earthquake resistant design for flexible structures. Later, in 1953, G. W. Housner et al. (2) calculated earthquake response spectra with consideration for the effect of damping. In 1959 G. W. Housner (3) proposed average spectra.

In Japan, T. Takata et al. (4) calculated earthquake response spectra of strong-motion records observed in that country and proposed average spectra from 20 horizontal acceleration records in 1964. The average spectra have been used in earthquake response analyses of public works such as highway bridges (5) and were adopted to the Japan Society of Civil Engineer's Specifications for Earthquake Resistant Design of the Honshu-Shikoku Bridges (1967) (6).

Recently T. Katayama (7) and S. Hayashi et al. (8) discussed effects of seismic and subsoil conditions on earthquake response spectra.

In this paper characteristics of earthquake response spectra of 44 components of strong-motion records measured during recent major earthquakes in Japan, are studied (9). The accelerograms are obtained by SMAC-type or DC-type strong-motion accelerographs. The records are selected so that the Richter magnitudes and the maximum accelerations may be over about five and 20 gals, respectively, and that the number of records classified in each group may be nearly equal.

Records on subsoil layers where liquefaction or faults were observed nearby are excluded.

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CLASSIFICATION OF RECORDS AND AVERAGE SPECTRA

The 44 records are classified into several groups in four ways, according to magnitudes, maximum ground accelerations, epicentral distances and subsoil conditions in order to examine the effects of these conditions on earthquake response spectra. Definition of subsoil conditions is shown in Table 1.

In this paper response spectra (represented by β-spectra) are defined to be the ratio of the response accelerations to the maximum ground acceleration, which means the magnification of the response accelerations of the vibrational systems to the earthquake ground acceleration.

Response spectra are classified into several groups in four ways and consequently they are averaged respectively in each group.

Four average spectra with damping ratio of 5% corresponding to four groups of records classified by magnitudes are shown in Fig. 1. It may be remarked that the average β-spectra for records observed during earthquakes with large magnitudes tend to show comparatively high level in the range of relatively long natural periods. For example, the average β-spectra with damping ratio of 5% for the groups with magnitude of 4.8 to 5.5 and of 7.5 to 7.9 are about 0.46 and 1.9, respectively, at 1 sec. of the natural period.

Five average spectra with damping ratio of 5% corresponding to five groups of records classified by maximum ground accelerations are shown in Fig. 2. It is difficult to find distinct difference between these spectra. However, it may be remarked that the β-spectra for the group of records with accelerations of 200 gals or more show comparatively low level in the period range around 1 sec.

Three average spectra with damping ratio of 5% corresponding to three groups of records classified by epicentral distances are shown in Fig. 3. It may be remarked that the average β-spectra for the group of records with great epicentral distances tend to show comparatively high level in the range of relatively long natural periods.

Five average spectra with damping ratio of 5% corresponding to five groups of records classified by subsoil condition are shown in Fig. 4. The fifth group is the union between the third and the fourth shown in Table 1. It may be remarked that the average β-spectra for the records obtained on stiff subsoil layers tend to be lower than the ones on soft subsoil layers in the relatively long natural periods. For example, the average β-spectra with damping ratio of 5% on rocky grounds and on soft alluvial grounds are about 1.0 and 1.8, respectively, at 1 sec. of natural period. The average spectra for rock, diluvium and stiff alluvium do not show much difference from one another in the period range around 1 sec. However, the average spectrum for soft alluvium show high level and much differ from the others in the same period range.

CONCLUSIONS

From above investigation the following conclusions may be drawn.

1) The average β-spectra for the records observed during earthquakes with large magnitudes show comparatively high level in the range of relatively long natural periods.
2) The spectra for the records with accelerations of 200 gals or more show comparatively low level.
3) The spectra for the records with great epicentral distances show comparatively high level.
4) The spectra for the records obtained on stiff subsoil layers are lower than the ones on soft subsoil layers.

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Table 1 Classification of 44 Records

Classification		Definition	Number of Records	Average Values		
				$\ddot{z}$ max (gal)	Richter's M	Δ (km/mile)
T O T A L			44	116.8	6.3	84/53
Magnitude (M)	MAG1	4.8 ~ 5.5	13	111.5	5.1	40/25
	MAG2	5.5 ~ 6.5	12	72.6	6.1	37/23
	MAG3	6.5 ~ 7.5	9	178.3	6.9	107/67
	MAG4	7.5 ~ 7.9	10	121.3	7.7	176/110
Acceleration ($\ddot{z}_{max}$)	ACC1	20 ~ 50 gals	10	38.4	6.2	86/54
	ACC2	50 ~ 75	10	60.1	6.2	64/40
	ACC3	75 ~ 120	9	92.6	6.3	91/57
	ACC4	120 ~ 200	9	163.2	6.5	124/78
	ACC5	200 ~ 438	6	308.6	6.3	42/26
Epicentral Distance (Δ)	DIS1	5 ~ 20 km (3 ~ 13 miles)	15	156.6	5.6	11/7
	DIS2	20 ~ 120 (13 ~ 75)	16	106.4	6.4	67/42
	DIS3	120 ~ 322 (75 ~ 201)	13	83.9	7.0	189/118
Subsoil Condition	GR 1	Rock	8	59.7	5.7	61/38
	GR 2	Diluvium	12	104.9	6.0	88/55
	GR 3	Alluvium 1 (Stiff)	10	94.3	6.6	59/37
	GR 4	Alluvium 2 (Soft)	14	175.7	6.7	89/56

The definition of classification of subsoil conditions is as follows.

GR 1: Bedrock or Diluvial or Alluvial layers with depth less than about three meters (10 feet) above bedrock.

GR 2: Diluvial layers.

GR 3: Alluvial layers which are stiffer than GR 4.

GR 4: Alluvial layers which have standard penetration test N-value of 10 or less extending from the surface to the depth of 10 meters (30 feet) or more.

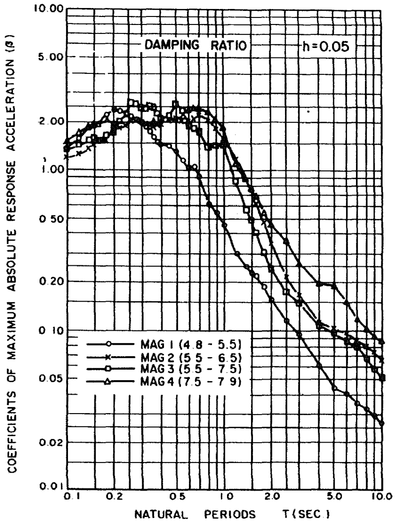

Fig. 1 Influence of Magnitude

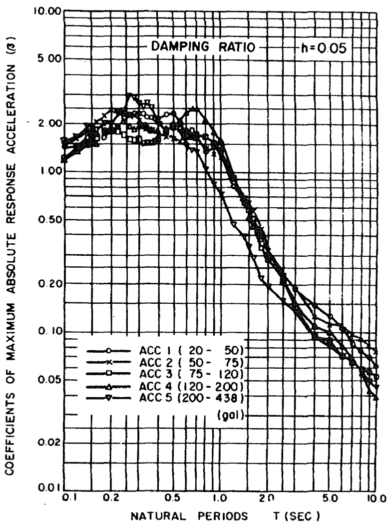

Fig. 2 Influence of Acceleration

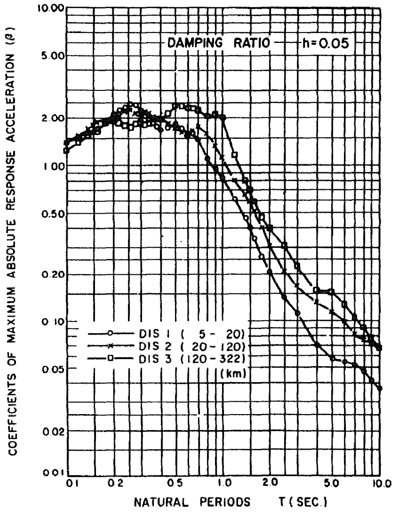

Fig. 3 Influence of Epicentral Distance

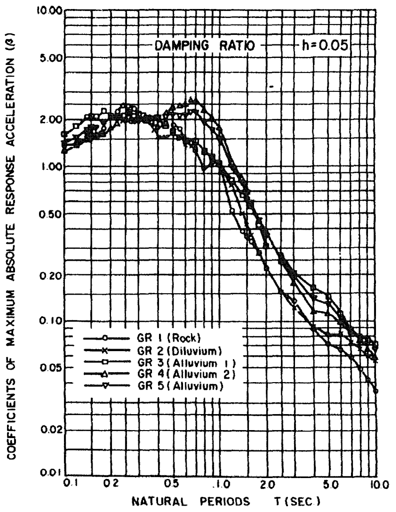

Fig. 4 Influence of Subsoil Condition