Prediction of peak vertical acceleration with classification of dependence factor on the ground motion

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INTRODUCTION

One of the characteristics of earthquake ground motion of considerable interest to engineers and seismologists is the maximum peak value of ground acceleration developed at any specific site during an earthquake. Because of its interest to engineers and seismologists, many studies have been conducted to study the attenuation of peak acceleration with increasing distance from the epicenter, the causative fault of the source of energy release of earthquakes, e.g. Gutenberg and Richter, (1956); Abrahamson & Litehiser (1989); etc.

Comparatively very few studies have been made to reveal the effect of site geology on the attenuation of acceleration. But most of these attenuation laws have not considered the site geology. In this paper the dependence of peak vertical acceleration on magnitude, epicentral distance and recording site geology for short to middle distance ranges using Japanese strong motion data have been analyzed. We have tried to get the effect of dependence factor on the peak vertical acceleration with good estimation of ground motion parameters at the site which is near to the real values of observed data. The influence of local site geology has been investigated by considering the site geology as an effective factor for estimation of vertical acceleration.

ANALYTICAL METHOD

First method of Hayashi's quantification theory of categorical data has been used for the analysis which is similar to the general multiple regression analysis, but the variables are not in the form of numerical values. The numerical data such as focal depth, magnitude and epicentral distance were converted to the categorical data.

The values of vertical acceleration is assumed as external criterion variable Y_i for i-th observation and magnitude, focal depth, epicentral distance, site conditions were considered as internal variables. Assume a set of data by N observed values and let the value sample i be denoted by Y_i, select R item that each item is then divided into several categories. Define a variable $X_{i(jk)}$ corresponding to category k in item j of sample i, thus determining a_{jk} as a weighting factor for category k in the item j. The estimation equation will be as follow:

$$A_v^i = \sum_{j=1}^{R} a_{jk}^i X_{i(jk)}^i + c \qquad (1)$$

where a_{jk}^i is score of category kj correspond to item j and X_{jk}^i is response value of item categories. C is the constant term which as derived by the analysis. The response scheme of item and categories is given in Table 1.

More than 220 Japanese strong motions data consisting of vertical component of acceleration observed during the past 18 years, were collected (Strong Motion Earthquake Observation Council 1975 - 1992). These data have been recorded by different type of accelerometers located on various ground conditions. The distribution of observational station with respect to their site geology is given in Figure 1.

SITE EFFECT

As was mentioned previously, Japanese data were obtained on various kind of grounds ranging from soft alluvium along coastal area to the Granitic rock at the mountainous area. To find out the effect of site condition on the predicted acceleration, the recording data were divided into 4 groups according to the site geology. The ground motion amplification factor at each observation site differ which is affected by the geological and geotechnical characteristics of the ground at the observatory stations.

Recording sites were classified into 4 detail categories namely, Rock, Hard, Medium, and Soft soil. The grouping was based on stiffness of the material and thickness of alluvial and diluvial layers at the stations which have been investigated and classified by individual organizations (e.g., Port and Harbour Research Institute, 1967 - 1980;).

The above three soil types are described as follows(Japan Society Civil Engineers, 1988); Hard: Ground before the tertiary period or thickness of diluvial deposit above bedrock is less than 10m; Medium: Thickness of diluvial deposit above bedrock is greater than 10m, or thickness of alluvial deposit above bedrock is less than 10m, or thickness of alluvial deposit is less than 25m and thickness of soft deposit is less than 5m; Soft: Other soft ground such as reclaimed land.

ANALYTICAL RESULTS

The multiple correlation coefficients of analysis reached to 0.8 and also partial correlation coefficient of items are calculated. The effective rate of variable to the estimation are demonstrated in term of partial correlation coefficients. Magnitude and epicentral distance with high partial correlations are the most significant factors and ground condition with moderate correlation have notable influence on the prediction analysis.

The ratios between observed and predicted accelerations are shown in Figure 2-(a). This Figure reveal that the vertical acceleration resulted from the analysis are approximately closed to the observed values.

There are some limitations on the prediction which are as follow: 1- Epicentral distance 10 - 200 km, 2- Magnitude 3.6 - 6.5 Ms, 3- Focal depth 10 - 100 km. The Focal depth is included as effective of path condition. This factor was almost neglected in the others works.

The effect of site geology to the ground motion can be observed from Figure 2-(b). The prediction curves related to the sites are clearly separated. Rock with higher estimation of vertical acceleration than those of soils.

Previously published attenuation relations for peak vertical acceleration are significantly different from analytical methods and considering the site conditions as an effective factor to the prediction, (e.g. Abrahamson and Litehiser 1989) point of view which quantitative analytical method were used by categorized numerical data with considering site conditions as an affective factor to predict of vertical acceleration by our study.

CONCLUDING REMARKS

The principle conclusions of this study can be summarized as following.

Most of the researchers have been worked on the relation between attenuation and peak acceleration without consideration of the site factor. In this study the site effect as an important factor for estimation of vertical acceleration has been investigated.

To clarify the significance of site effect on prediction of acceleration, Hayashi's quantitative analysis of qualitative data was used. The results show high multiple correlation coefficients indicating applicability of the method. High to acceptable correlation coefficient of variable were obtained which reveals the significant effect of factors to the estimation.

Our prediction method and the model of Abrahamson & Litehiser (1989) have been compared by testing a new set of data. It has been defined that our prediction has a good match with observations in the comparative figure.

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Table 1 Response scheme for item and category.

Outside Criterion	Item										
	1			---	j			---	R		
	Category										
	1	---	k_1	---	1	---	k_j	---	1	---	k_R
Y_1	$X_1(11)$	---	$X_1(1k_1)$	---	$X_1(j1)$	---	$X_1(jk_j)$	---	$X_1(R1)$	---	$X_1(Rk_R)$
Y_2	$X_2(11)$	---	$X_2(1k_1)$	---	$X_2(j1)$	---	$X_2(jk_j)$	---	$X_2(R1)$	---	$X_2(Rk_R)$
.	.		.		.		.		.		.
Y_i	$X_i(11)$	---	$X_i(1k_1)$	---	$X_i(j1)$	---	$X_i(jk_j)$	---	$X_i(R1)$	---	$X_i(Rk_R)$
.	.		.		.		.		.		.
Y_N	$X_N(11)$	---	$X_N(1k_1)$	---	$X_N(j1)$	---	$X_N(jk_j)$	---	$X_N(R1)$	---	$X_N(Rk_R)$

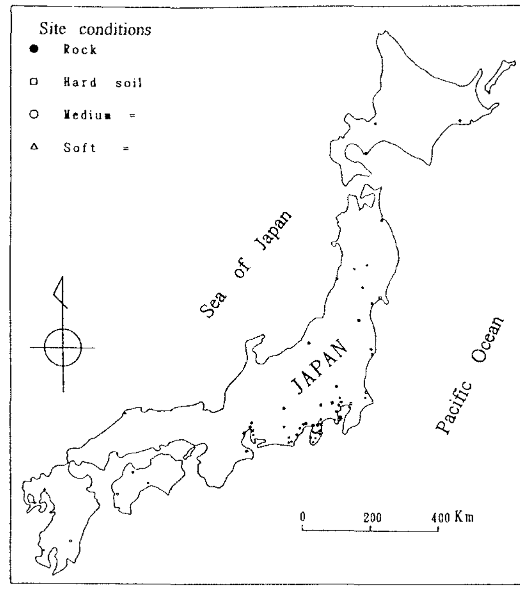

Fig.1 Distribution of observational stations with respect to various kind of ground.

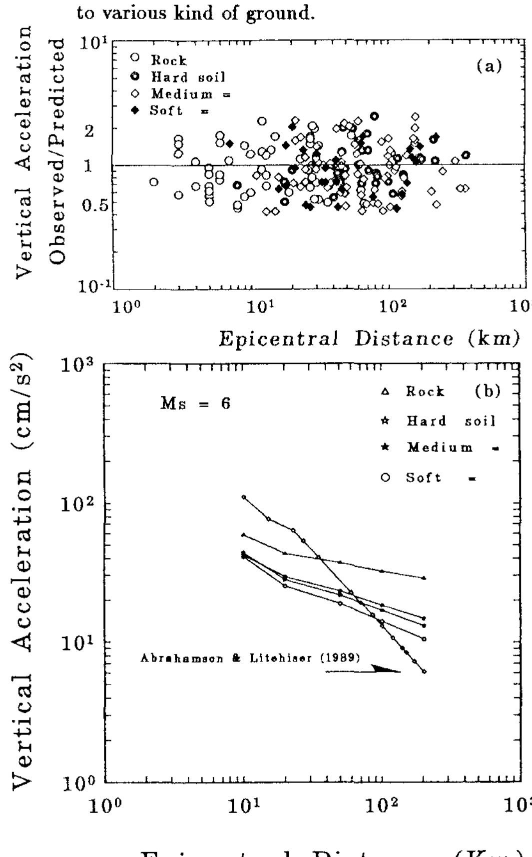

Fig.2 Vertical acceleration ratios between observed and predicted (a) and predicted vertical acceleration against epicentral distance with respect to magnitude 6 (Ms) for different site conditions(b).