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CONVERSION FACTORS FOR DIFFERENT DEFINITIONS OF PEAK VALUES OF GROUND MOTION INDICES

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INTRODUCTION: One of the characteristics of earthquake ground motions of considerable interest in design are the peak values of horizontal ground motions developed at specific site during an earthquake. The indices generally considered are: peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), acceleration response spectrum (ARS) and spectrum intensity (SI). Among these indices ARS may be a more relevant parameter to represent the characteristics of ground shaking as it accounts for both frequency and intensity of ground motion. SI has a better correlation with structural damage [3].This paper presents the analysis of normalized peak ground motion data from 1,368 horizontal acceleration records of 201 earthquakes at 78 free field sites of JMA and were recorded by the JMA-87 type accelerographs. The objective of this analysis is to examine the distribution of normalized ground motion indices and to find the conversion factors for the conversion of attenuation and damage estimation relationships developed for different definitions of peaks.

STRONG MOTION DATA USED: A total of 684 sets of two horizontal components of acceleration records were used in the analysis. Only earthquakes which has magnitude greater and equal to 4.0 and horizontal acceleration component in any direction 5 cm/s² or greater were considered in the analysis. Figure 1 shows distribution of events in terms of magnitude.

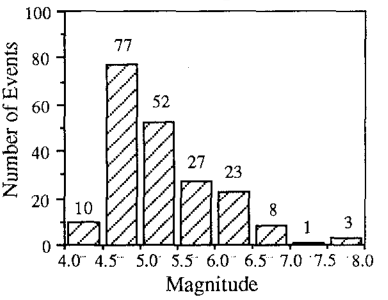

Fig. 1 Earthquake Events According to Magnitude.

Each pair of two orthogonal horizontal components was combined in time domain to get the maximum resultant peak ground motion in the horizontal plane. Then the average of the two peak values, the square root of the product of those values (i.e. $\sqrt{\alpha_{1max}*\alpha_{2max}}$, where α_{1max} and α_{2max} are the peak ground motion indices in two orthogonal directions) and the larger between those values were normalized by the maximum resultant ground motion [1,2]. The same procedure was followed for ARS (with 5% damping) and for SI.

In this study, the SI value is defined as the average velocity response spectrum of 20% damped single-degree-of-freedom system with natural periods between 0.1 s to 2.5 s [3] as

$$SI=\frac{1}{2.4}\int_{0.1}^{2.5} Sv(T, h=0.2)dT \qquad (1)$$

ANALYSIS OF PEAK GROUND MOTION: The resultant, average, root and larger values of two horizontal motions were determined for all the 684 records. Table 1 shows the mean and standard deviation of average/resultant, root/resultant and larger/resultant of the ground motion indices. Previous study [4] showed the maximum peak ground motions (PGA,PGV, and PGD) determined by combination of two horizontal components are about 8% greater in magnitude than the larger of the two horizontal components. In this study, we have found resultant PGA is about 8% greater, resultant PGV is about 9% greater and resultant PGD is about about 10% greater in magnitude than the larger of the two horizontal components.

Table 1 Mean and Standard Deviation () of the Ratios (Bk/B1) of Ground Motion Indices

Indices	B1	B2	B3	B4
PGA	1.000 (0)	0.833 (0.075)	0.821 (0.097)	0.934 (0.063)
PGV	1.000 (0)	0.819 (0.078)	0.806 (0.097)	0.926 (0.065)
PGD	1.000 (0)	0.782 (0.082)	0.761 (0.112)	0.913 (0.075)
ARS (0.5s)	1.000 (0)	0.809 (0.077)	0.794 (0.098)	0.924 (0.067)
SI	1.000 (0)	0.817 (0.065)	0.805 (0.088)	0.916 (0.054)

B1=Resultant,B2=Average,B3=Root,B4=Larger

Figure 2 shows the histogram and the cumulative distribution of average/resultant and larger/resultant of PGA. Theoretically, average/resultant ratio should lie between 0.5 to 1.0, root/resultant ratio between 0.0 to 1.0 and larger/resultant ratio between 0.707 to 1.0. The cumulative distribution of average/resultant and root/resultant show some kind of bounded distribution while larger/resultant shows distribution similar to trigonometric distribution as can be seen from Fig. 2(b). This is obvious for larger component between the two horizontal acceleration components corresponding to the maximum resultant as larger is the maximum between cosine or sine component of the resultant. In this analysis larger value is the larger PGA between the two horizontal acceleration components, so the distribution of larger/resultant ratio does not match the trigonometric distribution but is similar to it.

ANALYSIS OF ACCELERATION RESPONSE SPECTRUM AND SPECTRUM INTENSITY: The response of a SDOF system was first calculated assuming damping ratio (=0.05) and periods (considering 14 periods from 0.05 s to 10s) for two horizontal orthogonal directions. The resultant, average, root and larger values of responses for the two horizontal orthogonal directions were calculated. The previous study [4] showed that the maximum acceleration response spectrum (ARS) determined by the combination of two horizontal response components is about 15% to 20% greater in magnitude than the larger spectral amplitude between the two orthogonal directions. In this study, we have found that resultant ARS is about 7% to 9% greater in magnitude than the larger spectral amplitude between the two orthogonal directions.The cumulative distribution of average/resultant, root/resultant, and larger/resultant of ARS for period = 0.5 s is similar to the distribution for PGA as shown in Fig. 2.

The SI value for a particular direction was calculated using the equation (1). But for the calculation of resultant SI of two horizontal directions, at first the resultant velocity responses for the two directions were computed for periods 0.1s to 2.5s (with an increment of 0.05s) and then the equation (1) was used.In this study, we have found that the resultant SI is about 10% greater in magnitude than the larger SI between the two horizontal orthogonal directions. Figure 3 shows the histogram and the cumulative distribution of larger/resultant of SI. The distribution of larger/resultant of SI is different from the distribution of larger/resultant of peak ground motions and acceleration response spectrum due to its particular definition as given by equation (1).

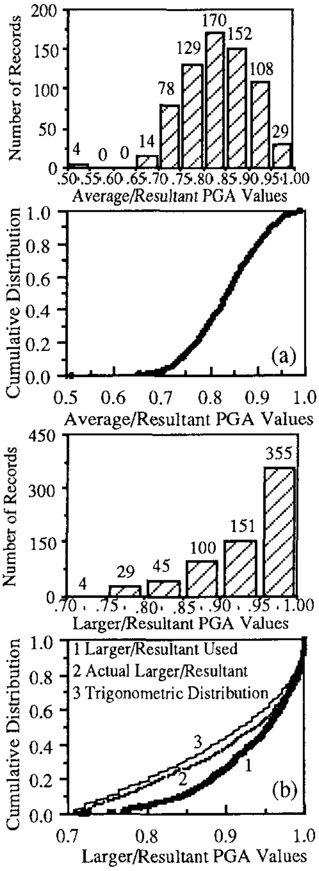

Fig. 2 Distribution of Average/ Resultant and Larger/Resultant Ratios of PGA.

CONCLUSION: The results of statistical analysis of peak ground motion, acceleration response spectrum and spectrum intensity were presented using 684 sets of horizontal strong motion records obtained at 78 free-field JMA stations. The following conclusions were obtained from the analysis:

1) Different ratios of peak ground motion or acceleration response spectrum or spectrum intensity used in this analysis are almost independent of magnitude, depth, and epicentral distance.
2) The ratios derived here can be used for the conversion of attenuation or damage estimation relationships developed for different definitions of peaks of the ground motion indices.
3) From the cumulative distribution, it was found that average/resultant and root/resultant values have some kind of bounded distribution and larger/resultant has distribution similar to trigonometric distribution.

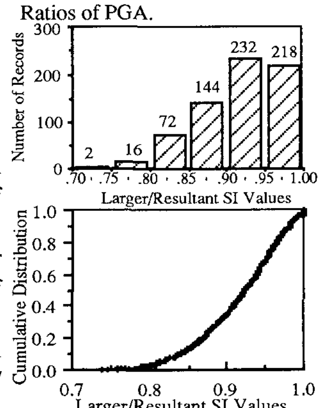

Fig. 3 Distribution of Larger/ Resultant Ratio of SI.

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