CORRELATION ANALYSIS OF GROUND MOTION PARAMETERS BASED ON NGA-WEST2 DATABASE

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Abstract

It is a very important problem to measure the damage intensity of earthquake to structures by using ground motion parameters in seismic research. However, there are more than 10 ground motion parameters describing the seismic strength, in order to select the most representative parameters in many parameters. Based on the NGA-West2 strong motion database, this paper selects 17 commonly used ground motion parameters. By using least squares method, and the correlation analysis of the selected parameters is carried out, some parameters with higher correlation coefficients are classified as a type, and one parameter is chosen as the representative. By correlation analysis, 7 representative ground motion parameters were selected from 17 ground motion parameters. The results show that there is a high correlation between the partial ground motion parameters, and only partial ground motion parameters can be enough to characterize the amplitude, duration and spectrum characteristics of the earthquake, which reduce the computational analysis.

Keywords: destructive strength, ground motion parameters, least square method, correlation analysis

1. Introduction

Earthquakes can cause great damage to building structures. For engineering structures in areas with more earthquakes, building seismic design is very important. With the development of engineering seismology studies, people realize that the degree of damage to buildings caused by earthquakes is determined by many factors, such as the frequency spectrum and amplitude of ground motion, the materials and dynamic characteristics of building structures, and so on [1]. Therefore, when describing the potential damage of earthquakes to building structures, multiple ground motion parameters need to be considered at the same time. How to use ground motion parameters to describe the potential damage of ground motions to building structure has always been a concern of seismologists. Xie and Zhai [2] have studied the most unfavorable ground motion by using ground motion parameters such as maximum incremental velocity (MIV), maximum incremental displacement (MID) and Arias intensity (AI); Liu et al [3] study the correlation between ground motion parameters and structural response of cable-stayed bridge. It is concluded that there is a good correlation between Housner intensity (SI), AI and structural response of cable-stayed bridge, so they can be used to characterize structural response. However, if multiple parameters are considered at the same time, there may be a strong correlation between multiple ground motion parameters and structural response, or the structural failure mechanism may be the same. If each ground motion parameter is calculated and analyzed in detail, a lot of calculation time is needed, and a lot of repetitive work may be carried out, and it is not easy to distinguish the damage degree of building structure according to different ground motion parameters. The amplitude parameters of ground motion are most widely used in seismic design of building structures; The parameters of ground motion can better reflect the cumulative damage effect of building structure [4]. Duration is divided into different categories. At present, more than 30 definitions of duration are proposed in the field of earthquake engineering, such as Bolt duration (D_b), significant duration (D_s) and so on [5]. Response spectrum is the foundation of building seismic design, and building structural design is closely related to structural dynamic characteristics [6].

At present, there are many kinds of ground motion parameters that characterize the characteristics of ground motion. In this paper, when selecting ground motion parameters, we should try our best to select the parameters with high frequency and representative in earthquake engineering. The selection of ground motion parameters should be comprehensive, covering the amplitude, duration and frequency spectrum of the three elements of ground motion. The correlation of selected ground motion parameters are analyzed, and their Pearson correlation coefficient and regression equation are obtained. One of the parameters with strong correlation is selected to replace the other parameters, which can reduce the number of ground motion parameters and ensure the comprehensiveness of the selected parameters.

2. Data sources

The ground motions selected in this paper come from the NGA-West2 database published by Pacific Earthquake Engineering Research Center (PEER) in the United States. there are two main reasons for choosing this database: first, the NGA-West2 database has the same format, which uses four rows of headers to introduce earthquake information such as earthquake name, station name, time interval, and so on. Records data starts from the fifth row [7]. The second reason is that the stations of NGA-West2 database are distributed all over the world, so we can collect ground motion records from all over the world [8].

At present, there are more than 59000 ground motion records collected in NGA-West2 database, which are divided into horizontal and vertical components. This paper uses 5537 horizontal ground motion records with peak ground acceleration (PGA) exceeds 50gal in the database; The station distribution of the collected records is shown in Figure 1, and the ground motion records are classified into four sites as shown in Table 1.

(a) (b) (c)

Fig. 1 – Distribution of stations of the selected 5535 ground motions. (a) North America; (b) Mediterranean and central and western Asia; (c) Taiwan, Japan and New Zealand.

Table 1 – Classification of ground motion records

Site classification	V_{s30} (m/s)	Number of ground motions
A	>760	108
B	360~760	2743
C	180~360	2534
D	<180	152

3. Selection of ground motion parameters

In this paper, ground motion parameters are used to describe the damage potential of ground motion. On one hand, the selection of ground motion parameters should be comprehensive, covering the amplitude, duration and frequency spectrum of the three elements of ground motion. On the other hand, the parameters with clear physical meaning, wide application range and high frequency in earthquake engineering are selected as far as possible. Therefore, 17 ground motion parameters [9-21] are selected through comparison and analysis as shown in Table 2.

Table 2 – Initial selection of ground motion parameters

Classification of ground motion parameters	Ground motion parameters
Amplitude parameters	Peak ground acceleration (PGA)
	Peak ground velocity (PGV)
	Peak ground displacement (PGD)
Duration parameters	Bracket duration (D_b)
	Uniform duration (D_u)
	Significant duration (D_s)
Spectrum parameters	Effective peak acceleration (EPA)
	Effective peak velocity (EPV)

	Housner intensity (SI)
	Spectral acceleration at 0.2 second (S_a0.2)
	Spectral velocity at 0.2 second (S_v0.2)
	Spectral displacement at 0.2 second (S_d0.2)
Energy parameters	Cumulative absolute velocity (CAV)
	Standard cumulative absolute velocity (CAVs)
	Maximum incremental velocity (MIV)
	Maximum incremental displacement (MID)
	Arias intensity (AI)

4. Correlation analysis of ground motion parameters

The correlation of 17 ground motion parameters is analyzed based on the ground motion records with peak acceleration greater than 50gal in NGA-West2 database [22, 23]. The correlation between ground motion parameters is analyzed, and the Pearson correlation coefficient is calculated. The results are shown in Table 3. The ground motion parameters with higher correlation coefficient are linearly fitted and the regression equation is calculated. It can be found that the correlation coefficients of various parameters are different, and the correlation coefficients of some ground motion parameters are more than 0.85 or even more than 0.90, indicating that these parameters have a strong correlation and can be classified into one category. Only one of the parameters needs to be selected for analysis. Four groups of ground motion parameters can be selected by statistical analysis.

Table 3 – Correlation coefficient among different ground motion parameters

Parameters	PGA	PGV	PGD	D_u	D_b	D_s	MIV	MID	AI	CAV	EPA	EPV	Sa0.2	Sd0.2	Sv0.2	SI	CAV_s
PGA	1.00	0.61	0.28	0.66	0.45	0.19	0.61	0.23	0.82	0.64	0.92	0.64	0.87	0.87	0.85	0.66	0.7
PGV	0.61	1.00	0.79	0.71	0.42	0.06	0.96	0.77	0.59	0.7	0.67	0.84	0.55	0.55	0.47	0.92	0.73
PGD	0.28	0.79	1.00	0.51	0.31	0.21	0.7	0.99	0.33	0.54	0.3	0.46	0.24	0.24	0.19	0.57	0.53
D_u	0.66	0.71	0.51	1.00	0.6	0.07	0.69	0.47	0.67	0.91	0.72	0.71	0.64	0.64	0.6	0.75	0.95
D_b	0.45	0.42	0.31	0.6	1.00	0.21	0.4	0.28	0.55	0.7	0.49	0.41	0.44	0.44	0.43	0.44	0.68
D_s	0.19	0.06	0.21	0.07	0.21	1.00	0.06	0.22	0.02	0.35	0.16	0.01	0.18	0.18	0.19	0.04	0.2
MIV	0.61	0.96	0.7	0.69	0.4	0.06	1.00	0.67	0.58	0.69	0.66	0.87	0.54	0.54	0.45	0.94	0.71
MID	0.23	0.77	0.99	0.47	0.28	0.22	0.67	1.00	0.28	0.49	0.25	0.42	0.19	0.19	0.14	0.53	0.48
AI	0.82	0.59	0.33	0.68	0.55	0.02	0.58	0.28	1.00	0.75	0.79	0.63	0.72	0.72	0.71	0.65	0.79
CAV	0.64	0.7	0.54	0.91	0.7	0.35	0.69	0.49	0.75	1.00	0.7	0.69	0.61	0.61	0.57	0.74	0.98
EPA	0.92	0.67	0.3	0.72	0.49	0.16	0.66	0.25	0.79	0.7	1.00	0.71	0.93	0.93	0.9	0.73	0.75
EPV	0.64	0.84	0.46	0.71	0.41	0.01	0.87	0.42	0.63	0.69	0.71	1.00	0.57	0.57	0.47	0.95	0.72
Sa0.2	0.87	0.55	0.24	0.65	0.44	0.18	0.54	0.19	0.72	0.61	0.93	0.57	1.00	1.00	0.99	0.6	0.66
Sd0.2	0.87	0.55	0.24	0.65	0.44	0.18	0.54	0.19	0.72	0.61	0.93	0.57	1.00	1.00	0.99	0.6	0.66
Sv0.2	0.85	0.47	0.19	0.6	0.43	0.19	0.45	0.14	0.71	0.57	0.9	0.47	0.99	0.99	1.00	0.5	0.63
SI	0.66	0.92	0.57	0.75	0.44	0.04	0.94	0.53	0.65	0.74	0.73	0.95	0.6	0.6	0.5	1.00	0.77
CAV_s	0.7	0.73	0.53	0.95	0.68	0.2	0.71	0.48	0.79	0.98	0.75	0.72	0.66	0.66	0.63	0.77	1.00

Table 4 – Correlation coefficient between EPA and Sa0.2, Sv0.2, Sd0.2 and PGA

Parameters	**Sa0.2**	**Sv0.2**	**Sd0.2**	**EPA**	**PGA**
Sa0.2	1.00	0.99	1.00	0.93	0.87
Sv0.2	0.99	1.00	0.99	0.90	0.85
Sd0.2	1.00	0.99	1.00	0.93	0.87
EPA	0.93	0.90	0.93	1.00	0.92
PGA	0.87	0.85	0.87	0.92	1.00

(1) The correlation coefficients among Sa0.2, Sv0.2, Sd0.2, PGA and EPA are all above 0.85. As shown in Table 4, EPA can be used to replace other parameters. Linear fitting analysis are carried out between EPA and Sa0.2, Sv0.2, Sd0.2 and PGA, the fitting results are shown in Figure 2, and the linear regression equations are obtained as shown in Table 5.

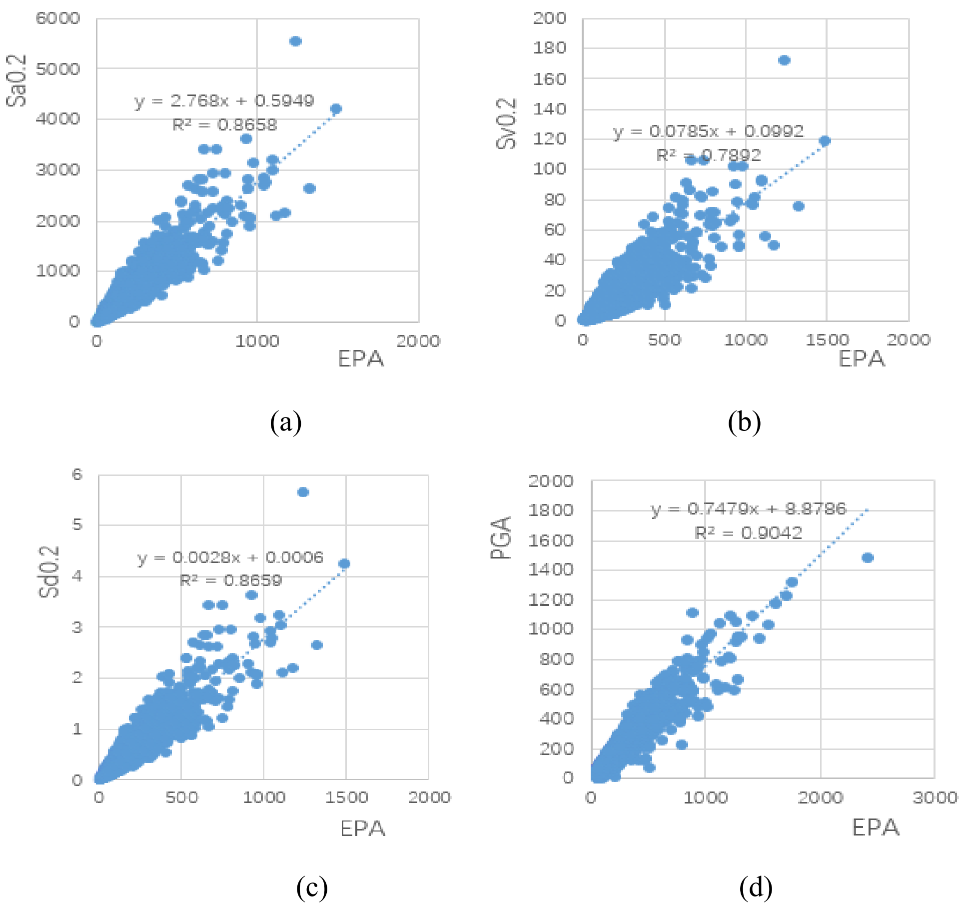


Fig. 2 – Linear fitting result between EPA and Sa0.2, Sv0.2, Sd0.2 and PGA

Table 5 – Regression equations between EPA and Sa0.2, Sv0.2, Sd0.2 and PGA

y	**x**	**Regression equations**	**Correlation coefficients**
Sa0.2	EPA	$y = 2.768x + 0.5949$	0.93

Sv0.2	EPA	y = 0.0765x + 0.0992	0.89
Sd0.2	EPA	y = 0.0028x + 0.0006	0.93
PGA	EPA	y = 0.7479x + 8.8786	0.95

(2) The correlation coefficient between PGD and MID is 0.99. Linear fitting analysis is carried out between PGD and MID, the fitting results is shown in Figure 3, and the linear regression equation is obtained as shown in Table 6.

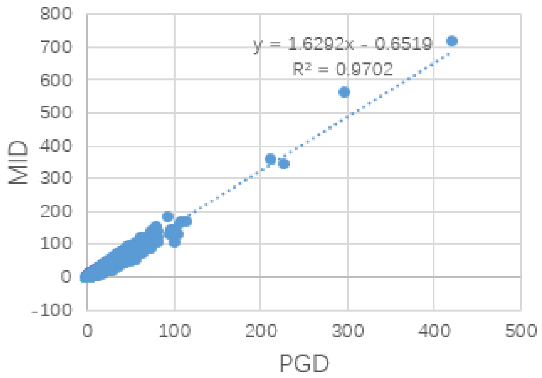
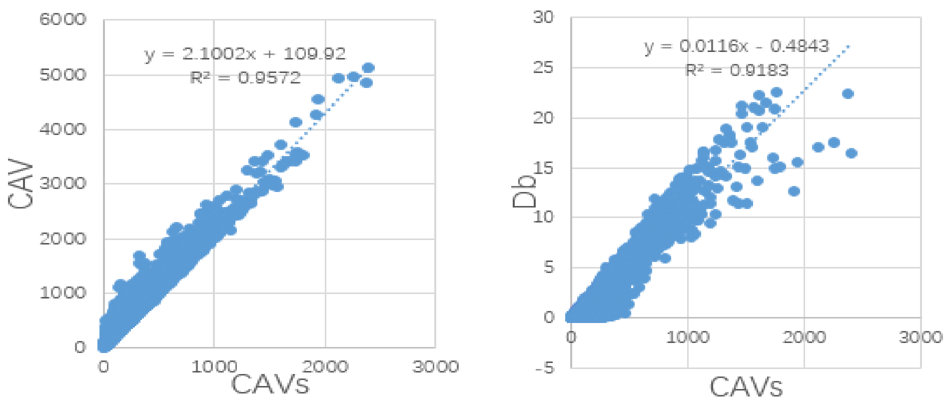


Fig. 3 – Linear fitting results between PGD and MID

Table 6 – Regression equation between PGD and MID

y	x	Regression equation	Correlation coefficient
MID	PGD	y = 1.6292x + 0.6519	0.99

(3) The correlation coefficients among CAV and CAV_s and D_b are all more than 0.90. the calculated results are as shown in Table 8, and CAV_s can be used to replace other parameters. Linear fitting analysis are carried out between CAV_s and CAV and D_b, the fitting results are shown in Figure 4, and the linear regression equations are obtained as shown in Table 8.



(a) (b)

Fig. 4 – Linear fitting results between CAV_s and CAV and D_b

Table 8 – Regression equations between CAV_s and CAV and D_b

y	x	Regression equations	Correlation coefficients
CAV	CAV_s	$y = 2.1002x + 109.92$	0.98
D_b	CAV_s	$y = 0.0116x - 0.4843$	0.95

(4) The correlation coefficients among PGV, MIV, SI and EPV are all more than 0.90. the calculated results are as shown in Table 9, and EPV can be used to replace other parameters. Linear fitting analysis are carried out between EPV and PGV, MIV and SI, the fitting results are shown in Figure 5, and the linear regression equations are obtained as shown in Table 10.

Table 9 – Correlation coefficients between EPV and PGV, MIV and SI

Parameters	PGV	MIV	SI	EPV
PGV	1.00	0.96	0.92	0.85
MIV	0.96	1.00	0.95	0.88
SI	0.92	0.95	1.00	0.95
EPV	0.85	0.88	0.95	1.00

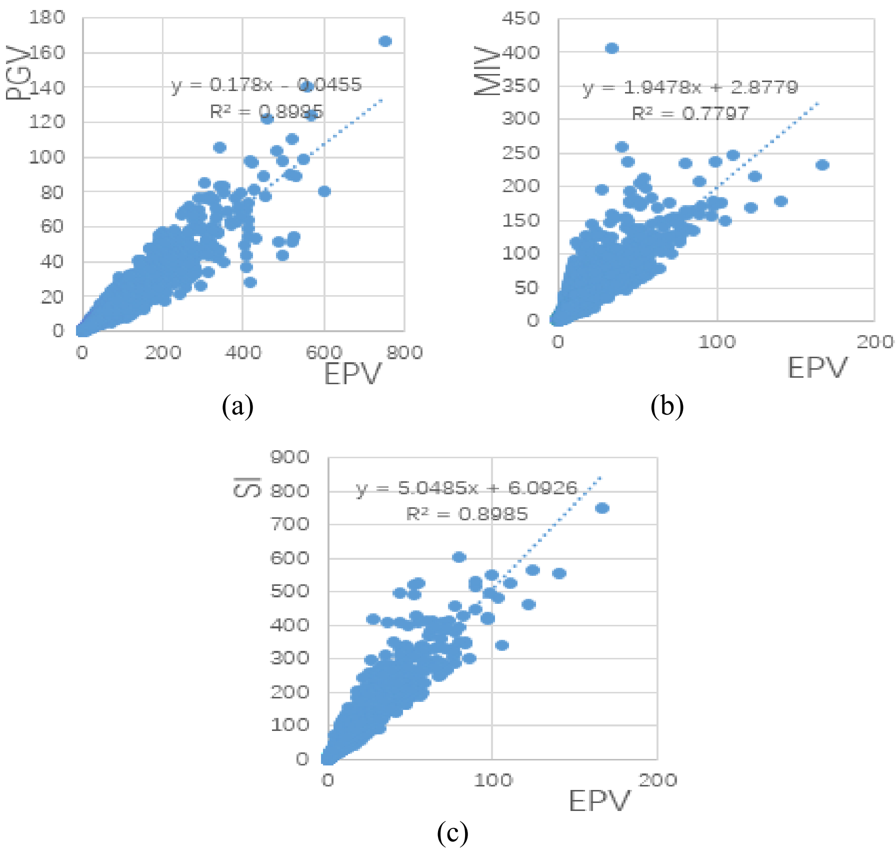


Fig. 5 – Linear fitting results between EPV and PGV、MIV and SI

Table 10 – Regression equations between EPA PGV、MIV and SI

y	x	回归方程	相关系数 R
PGV	EPV	$y - 0.178x - 0.0455$	0.85
MIV	EPV	$y = 1.9478x + 2.8779$	0.88
SI	EPV	$y = 5.0485x + 6.0926$	0.95

Through the analysis, 14 ground motion parameters can be divided into four groups, and the EPA, PGD, CAVs and EPV are selected from each group to represent other parameters; the correlation coefficients of D_b, D_s, AI with other parameters are small, so they need to be considered separately. Therefore, 7 of 17 ground motion parameters are selected. On the basis of ensuring the comprehensive analysis of the characteristics of ground motion, the number of ground motion parameters that need to be analyzed is greatly reduced.

5. Conclusion

In this paper, the horizontal component ground motion records with PGA larger than 50gal in NGA-West2 database are selected for analysis, and the ground motion parameters are calculated and the correlation analysis are carried out. The selection of ground motion parameters includes the amplitude, duration and frequency spectrum of ground motion, which reflects the comprehensiveness of the selection of ground motion parameters. Through the correlation analysis, the correlation coefficient of multiple parameters is larger, there is a strong correlation, and multiple parameters can be linearly represented by one parameter. Seven ground motion parameters including EPA, PGD, CAV_s, EPV, D_b, D_s and AI are selected from 17 ground motion parameters. On the basis of ensuring the comprehensive analysis of the characteristics of ground motion, the number of ground motion parameters that need to be analyzed is greatly reduced.

6. Acknowledgements

The work is supported by the National Key R&D Program of China (2018YFC1504401, 2017YFC1500403) and National Natural Science Foundation of China (U1939210). The authors also appreciate the assistance of the Pacific Earthquake Engineering Research Center (PEER) in providing the strong motion records.

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