EMPIRICAL PEAK GROUND VELOCITY ATTENUATION RELATIONS BASED ON DIGITAL BROADBAND RECORDS

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ABSTRACT :
Peak ground velocity (PGV) is very important to some large structures and buried pipelines. Previous PGV attenuation studies were mostly based on the integration to time histories of analog acceleration records which would inevitably introduce bias. In this paper we develop empirical attenuation relations for horizontal component of peak ground velocity in rock and soil sites. The strong motion datasets used to obtain the equations are recorded by Southern California Seismic Network. The digital broadband seismographes can directly record ground velocity and therefore can avoid errors of integration to acceleration records. 38 earthquakes with ML>5 from 1991 to 2001 were chosen, including 1992 Landers, 1994 Northridge, 1999 Hector earthquakes. The epicentral distance is up to 400 km. The site classification scheme was based on the averaged shear-wave velocity in upper 30m. 59 out of about 200 stations (i.e. approximate 30%) were grouped into rock site station. There are total 597 recordings for rock and 497 recordings for soil. An unweighted least-squares regression analysis was performed. Both horizontal components recorded at the same station were used independently. The PGV attenuation curves of rock and soil site have the similar trends for the same magnitude and distance, and the PGV on soil site is always larger. Comparisons with Huo(1989) was also illustrated, whose relations were calculated from velocity integrated from acceleration records. The curves have showed that for small earthquakes both equations have the same trends for rock, but he predict smaller values as the magnitude increases due to manually digitizing and low-cut filter. For soil, however, there are a significant discrepancy: his prediction decays more slowly than ours, leading to the prediction of our equation would be larger than Huo(1989) for the short distances, and smaller for the long distances, whether large magnitude or small.

KEYWORDS:
ground motion, peak ground velocity, attenuation relation, broadband record

1. INTRODUCTION

The responses of buried pipelines and some large structures to earthquake are dominated by ground motion velocity. Consequently, developing the attenuation relation for PGV to determine the shock resistant parameters of these structures in reason is very important. Some studies about the attenuation for PGV have been published. Their consistency is that the data sets they used are all analog strong motion acceleration recordings, whose time histories were digitized and integrated to velocity time histories in which the peak velocity were measured to obtain the attenuation for PGV using experience statistical method. However, in the digitalization of acceleration time history it was inevitable to introduce the bias making deviation to PGV, and then to the reliability of the attenuation relationship. The characteristics of the digital broadband seismograph include the broad frequency band, the large dynamic range and the high accuracy; and the time history recorded without the necessary for digitalization accordingly avoiding the error from manual digitalization. What's more important is that the amplitude-frequency response is flat for velocity in a very large period range, i.e. it records the ground motion velocity in its working frequency band. So there is great advantage in researching the characteristic of ground motion velocity with the digital broadband recordings. In this paper we develop the attenuation relations of the southern California area of America where there are abundant digital broad band data using empirical method for horizontal component of peak ground velocity in rock and soil sites. Compared with the results from analog recordings, the results of this paper are reasonable.

2.DATASET

The southern California seismic network in America has engaged on digital broad band seismic observation since later 1980s. Presently there are more than 200 digital seismographs working, which commonly are Streckeisen STS-1 or STS-2 tri-component seismograph providing export from the broad band high gain channel (BH) with the sampling rate of the signal is ordinary 20sps. Figure 1 illustrates the amplitude-frequency characteristic curves of the two types of digital broad band seismograph. The response to velocity is level from the period 0.1s to dozens of seconds which is very ideal to investigate the characteristic of the ground motion velocity.

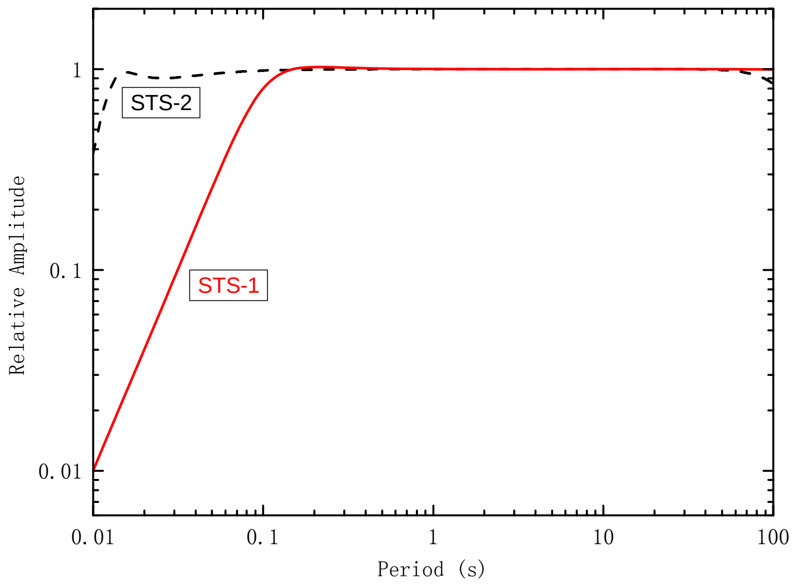

Figure 1 Amplitude response of 2 broadband seismographs. The response is relative to velocity.

In this paper the site categories of all the stations are classified into rock and soil in general. In the vicinity of Los Angeles in America, the site category is rock if the averaged shear wave velocity in the upper 30m is larger than 500m/s. For the other stations, according to the geological map of California with the scale 1:750,000 and the map of the shear wave velocity distribution in California, the geology before the Tertiary or the B class site (the averaged shear wave velocity in upper 30m is larger than 760m/s) and the BC class site (the averaged shear wave velocity in upper 30m is from 555m/s to 1000m/s) are rock.

Based on the scheme above, there are 59 rock sites of the about 200 stations in southern California, around 30%.

The data sets we used the digital broad band recordings from 38 earthquakes with ML > 5 between 1991 and 2001, including 1992 Landers earthquake, 1994 Northridge earthquake and 1999 Hector earthquake etc as shown in the table 1.

Table 1 Earthquake Catalogues

Serial Number	Time Y/M/D	Location		Magnitude M_L
		Longitude(°)	Latitude(°)	
1	1991/06/28	-l17.99	34.27	5.8
2	1992/06/28	-116.43	34.13	5.3
3	1992/04/23	-116.32	33.96	6.1

4	1992/06/28	-116.44	34.20	7.3
5	1992/06/28	-116.92	34.18	5.1
6	1992/07/05	-116.32	34.58	5.4
7	1992/07/11	-118.07	35.21	5.7
8	1992/07/24	-116.29	33.90	5.0
9	1992/08/17	-116.86	34.19	5.0
10	1992/09/15	-116.36	34.06	5.1
11	1992/11/27	-116.90	34.34	5.4
12	1992/12/04	-116.90	34.37	5.2
13	1993/05/17	-117.77	37.16	6.2
14	1993/05/28	-119.10	35.15	5.2
15	1993/08/21	-116.32	34.03	5.0
16	1994/01/17	-118.54	34.21	6.7
17	1994/01/17	-118.70	34.33	5.6
18	1994/01/19	-118.70	34.38	5.1
19	1994/01/29	-118.58	34.31	5.1
20	1994/03/20	-118.47	34.23	5.2
21	1994/06/16	-116.40	34.27	5.0
22	1995/06/26	-118.67	34.39	5.0
23	1995/08/17	-117.66	35.78	5.4
24	1995/09/20	-117.63	35.76	5.5
25	1996/01/07	-117.65	35.77	5.2
26	1999/10/21	-116.40	34.86	5.0
27	1999/10/21	-116.39	34.87	5.1
28	1996/11/27	-117.65	36.08	5.3
29	1997/03/18	-116.82	34.97	5.0
30	1997/04/26	-118.67	34.37	5.1
31	1998/03/06	-117.64	36.07	5.2
32	1998/03/07	-117.62	36.08	5.0
33	1998/07/15	-118.78	37.60	5.3
34	1999/08/01	-116.97	37.53	6.0
35	1999/08/02	-117.09	37.38	5.0
36	1999/10/16	-116.27	34.59	7.0
37	1999/10/16	-116.25	34.43	5.0
38	2001/02/10	-116.95	34.29	5.1

Both horizontal components are considered independently. Hence, there are 1144 recordings from 35 earthquakes with the magnitude larger than 5, composed of 597 rock and 547 soil recordings, whose epicentral distances range from 0km to 400km and magnitudes range from 5 to 7.5. Figure 2 and the Figure 3 are magnitude-distance distribution of rock and soil site data, respectively.

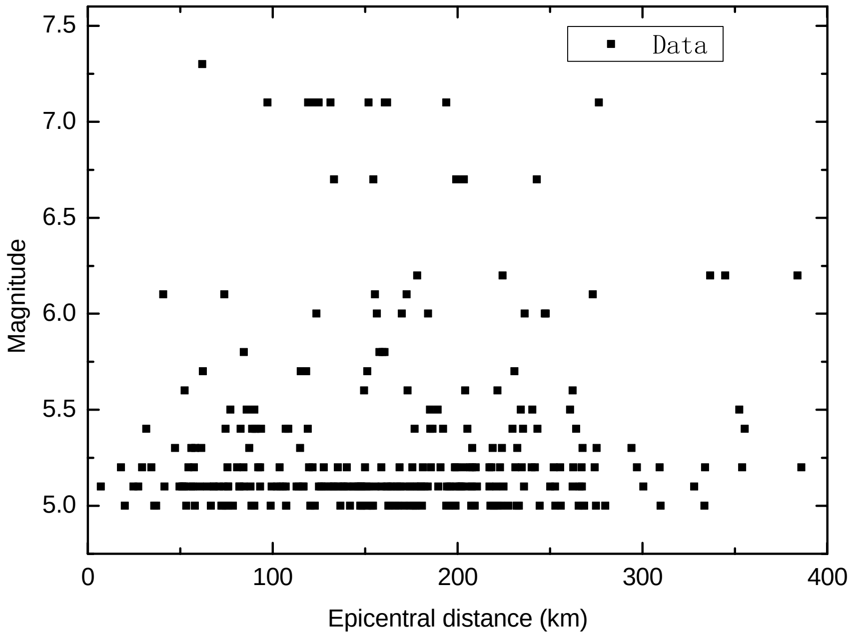

Figure 2 Magnitude-distance distribution of rock site data

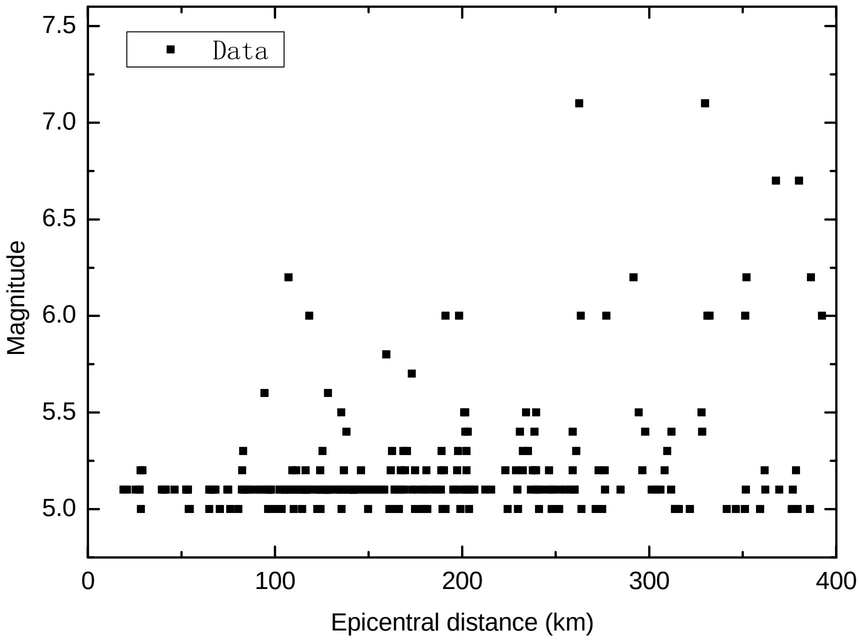

Figure 3 Magnitude-distance distribution of soil site data

3. RESULTS AND ANALYSIS

The model of the attenuation relationship is:

$$\lg Y = c_1 + c_2 M + c_3 \lg(R + R_0) + \varepsilon \quad (1)$$

Where Y is the PGV, unit is in m/s (cm/s), M is the magnitude, R is the epicentral distance, unit in km, c_1, c_2, c_3, R_0 is constants, obtained by the regression analysis, ε is the random quantity of the normal distribution with the mean is 0 and variance is σ.

The coefficients of the equation above obtained from regression analysis is listed in the table 2.

Table 2 Coefficients of peak ground velocity attenuation relations for rock and soil sites

Site category	c_1	c_2	c_3	R_0	σ
rock	-0.848	0.775	-1.834	17	0.290
soil	-0.285	0.711	-1.851	17	0.307

Figure 4 is the attenuation curves of PGV for rock and soil sites. As shown, both the two curves have the same trend, and the PGV of soil site is larger than the PGV of rock at the uniform magnitude and epicentral distance, which is consistent with observation.

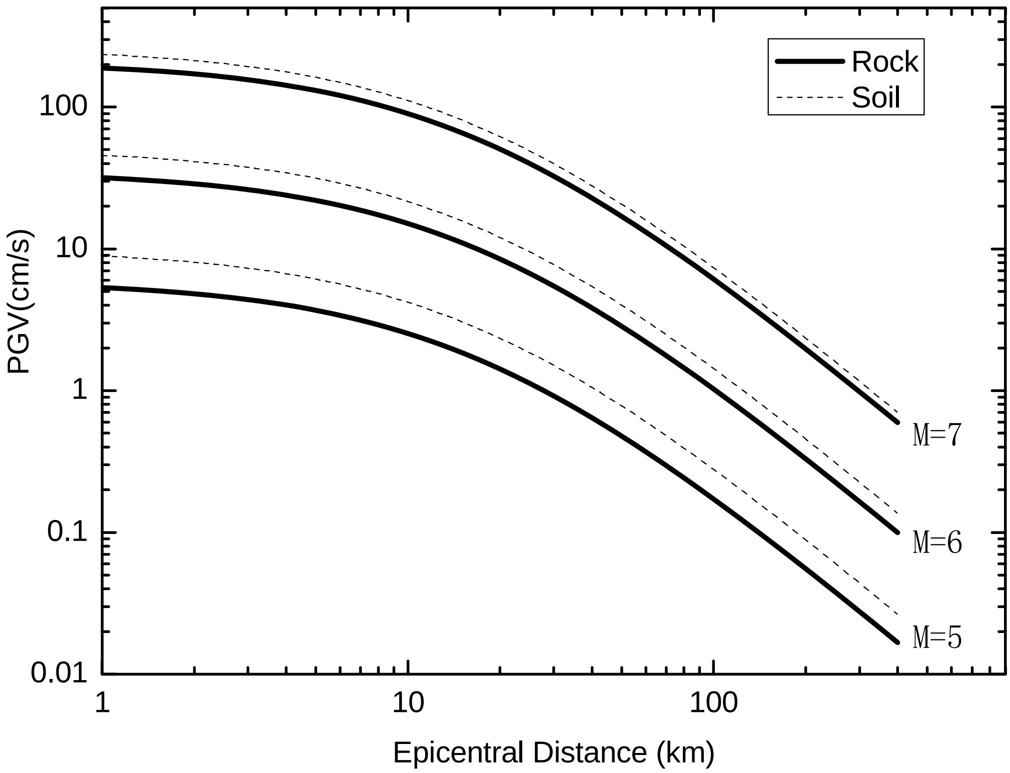

Figure 4 Attenuation curves of peak ground velocity for rock and soil sites

Figure 5 is the Comparison of PGA attenuation relations for rock site with Huo(1989), who used analog recordings.

Both attenuation curves are very close and have the consistent decay trend between the magnitude 5 and 6. At larger magnitude, Huo’s result is lower than ours. It’s because simulative recordings need digitalization and different kinds of correction, but the digitalization may introduce long period error which will control the ground motion values at the long period of the lower data from the middle and small earthquakes. Consequently the signal to noise ratio of ground motion velocity at smaller magnitude is so low that the PGV is controlled by the bias and overestimate the PGV. In the correction of simulative recording the most important step is highpass filtering with the objective to remove the long period error. However, pass filtering will inevitably influence the ground motion velocity dominated by long period ground motion, as a result, underestimating the PGV. The data sets we used are directly velocity recordings, without the necessary for correction just like the high-pass filtering, which are very proper for study on PGV.

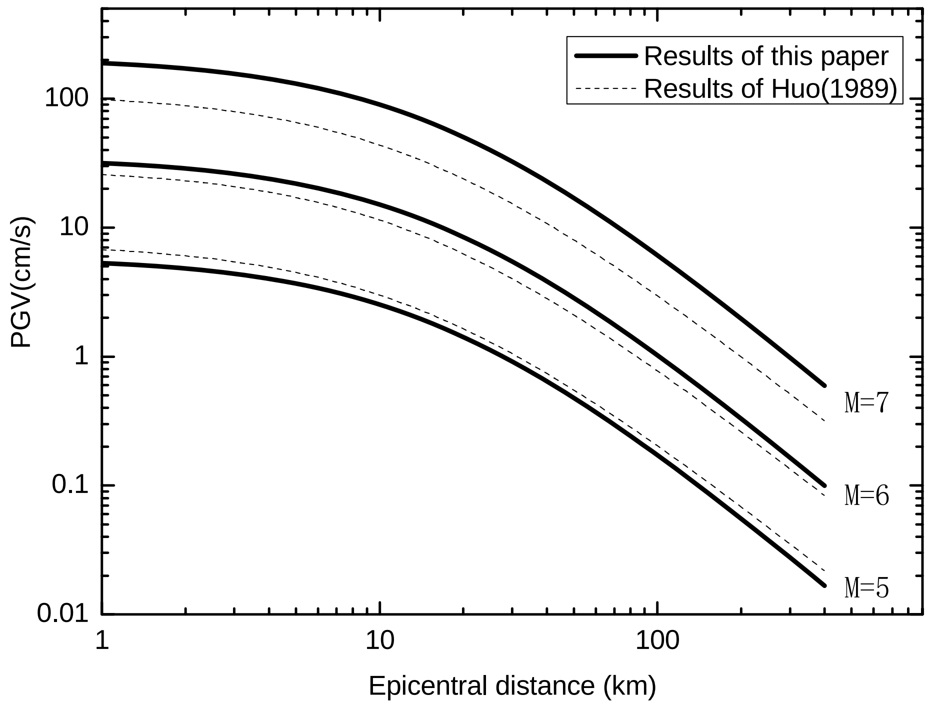

Figure 5 Comparison of PGA attenuation relations for rock site with Huo(1989)

Figure 6 is the comparison of PGA attenuation relations for soil site with Huo(1989). The main difference is Huo's results decay slower, leading our results larger at smaller distances but smaller at larger distances, either for large or small earthquakes.

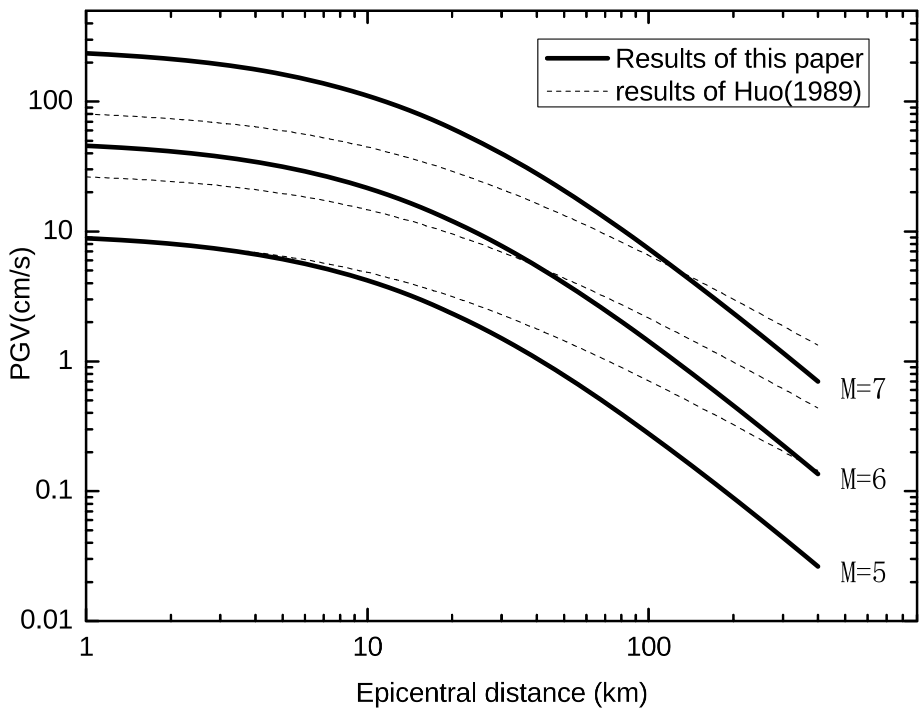

Figure 6 Comparison of PGA attenuation relations for soil site with Huo(1989)

4. CONCLUSIONS

In this paper we use the velocity data recorded by digital broadband seismograph to obtain the attenuation for PGV, having avoided the bias introduced by using the simulative strong motion recordings in the manual digitalization and difference kinds of correction process. The attenuations obtained in this paper are meaningful to examine the shock resistant parameters of the buried pipelines and the great engineering controlled by the ground motion velocity.

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