黄土覆盖山地对岷县、漳县M_S6.6地震余震动力响应的影响

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摘要：2013年7月22日岷县、漳县M_S6.6地震发生后，我们立刻在极震区架设三台K2强震动记录仪器，以了解地震对黄土覆盖山地的影响。截至8月11日共获取地震记录172个(516条)，M_L≥3.0的地震48个，最大震级M_L4.4，最大加速度值65.9 gal。我们从永星台阵的强余震观测资料中，选取震级较大的余震记录进行分析，经过初步处理，分别读取各个台站的地表最大加速度值，由于观测地区的黄土覆盖层较薄，土质松软，永星村台、永星小学台这两个台的加速度记录，不能与大竜村台的记录直接比较，我们将观测记录进行傅里叶分析，统计其优势频率，展示部分典型记录的傅里叶谱发现，黄土对高频成分的吸收作用不可忽视，最大加速度值随震中距的增大而衰减迅速。在近场情况下，地表最大加速度对震中距十分敏感，所以无法直接对比不同地形对于地表加速度的影响，分析结果表明：大竜村台优势频率为5.2 Hz；永星村台优势频率为4.1 Hz；永星小学台优势频率为5.3 Hz，注意到位于山脚下的大竜村测点为基岩，加速度记录的优势频率自然较高，而位于山顶的永星村是黄土地基，但是此地的加速度记录的优势频率明显高于山腰记录，几乎与基岩台基的优势频率相当。宏观调查也表明：低频率、高烈度对于房屋的破坏力更大。

M_L3.8地震观测表明，地表加速度值随震中距的增大而迅速衰减，距离最近的大竜村台(基岩台址)获取的加速度记录北南向最大，另外两个分向的加速度记录也大于较远的两个流动台的记录。基岩台北南向比垂直向要大，和这次地震的震源机制(逆冲兼走滑)相关。地形影响依然存在，本次观测台阵中，位于山顶的永星村观测记录的傅里叶谱，明显高于山腰的记录，地表最大加速度值也稍高于山腰观测，由于地形相差不够大，规律性也不太明显。本次观测结果和以往在孤立山峰的观测情况略有不同，一是记录地震的震级偏小，而观测距离又偏近，震中距的影响可能超过地形因素的影响程度，所以其原因更加复杂，有待进一步研究。

关键词：岷县-漳县M_S6.6地震；余震；黄土覆盖区；加速度；强震动仪台阵
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Influence of Aftershocks of the Minxian-Zhangxian M_S6.6 Earthquake in a Loess-rich, Hilly Region

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Abstract: Minxian-Zhangxian M6.6 earthquake occurred on July 22, 2013 in Dingxi, Gansu province. Shortly after the earthquake, we placed eight digital flow strong motion observation recording instruments in the surrounding area which were produced by Kinemetrics Company in the USA. We set

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up three K2 strong motion recording instruments in Yongxing village, Yongxing primary school and Dalong village. A large number of seismic records that can be used to better understand the effects of earthquakes on the loess layer were obtained. Up to August 11, 172 (516) seismic records were acquired, including 48 earthquakes of magnitude $M_L \geqslant 3$. The maximum magnitude was M_L4.4, and the maximum acceleration value was 65.9 gal. From the observed data of strong aftershocks from the Yongxing array, we selected records of large magnitude aftershocks for analysis. The Minxian M_L 3.8 earthquake record from August 8th was the largest, and we focused on those results. The results showed that the maximum acceleration value decayed rapidly with increasing distance from the epicenter, and the largest acceleration value was from Dalong village station, which was the nearest station from the epicenter. Because of the presence of a thin and soft loess layer in the observation area, the acceleration records from the Yongxing village station and the Yongxing primary school station could not be directly compared with those from Dalong village, but we conducted a further spectrum analysis on each record, and the effect of absorption by loess on the high-frequency components was significant. To further explore the impact of topography on the observed values, we further expanded the scope of the data filtering, and used the seismic data of four $M_L \geqslant 2.5$ earthquakes as the basis for measuring the peak ground acceleration value of each station. We conducted Fourier analysis on the records, obtained the dominant frequencies, and illustrated the Fourier spectrum of some typical records. The results show that the dominant frequency of Dalong village is 5.2 Hz, that of Yongxing village is 4.1 Hz and that of Yongxing primary school is 5.3 Hz. Noted that Dalong village was in foothills and its observation point was bedrock, the dominant frequency of acceleration was higher. The survey also showed that low frequency and high intensity events had greater destructive power for buildings. The seismic observation of M_L3.8 earthquake indicated that the acceleration records of NS direction of bedrock point are larger than vertical direction, which is related to the focal mechanism of the earthquake. The observation results are slightly different than the previous observation in isolated peaks, because the magnitudes of earthquakes are small, and the observation distance is near, the influence of epicentral distance may exceed the influence of topographic factors, which is too complex to be further studied.

Keywords: Minxian-Zhangxian M6.6 earthquake; aftershocks; loess area; acceleration; strong motion recording instrument

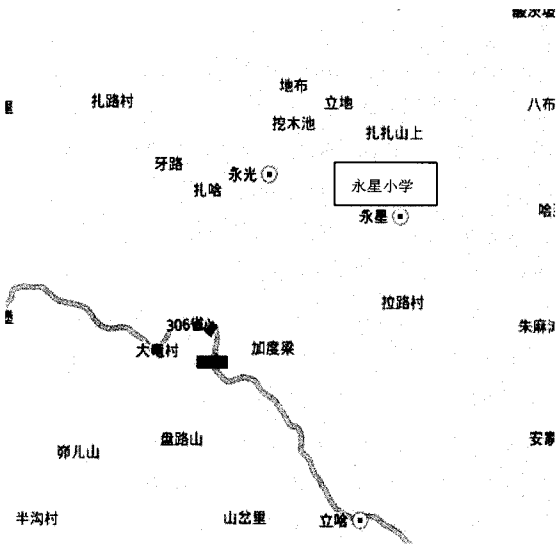
0 引言

2013年7月22日甘肃省岷县、漳县交界处发生 M_S6.6地震，当天接甘肃省地震局应急处的通知，我们携带了6台(套)美国凯尼公司生产的数字流动强震动观测记录仪器(型号：K2，技术参数见表3)赶赴震区，以最快速度分别在极震区梅川镇茶固村、梅川镇镇政府、茶埠镇镇政府架设三台(套)强震动记录仪器。于23日又在梅川镇红星村、西江镇铁池村、梅川镇板子沟村架设三台(套)强震动记录仪器。为了更好的了解地震对黄土覆盖层的影响，根据局(所)领导和专家的意见，7月29日我们到永光、永星村一带选择不同黄土地型的场地建立观测台阵。30日拆除西江镇铁池村及梅川镇红星村流动强震台，将它们架设在梅川镇永星村山顶农家和梅川镇永星小学(山腰)，8月3日补充架设了茶埠镇大竜村强震台，完成了流动强震对比观测台阵的部署。该强震仪台阵在其后记录了大量的余震信息。

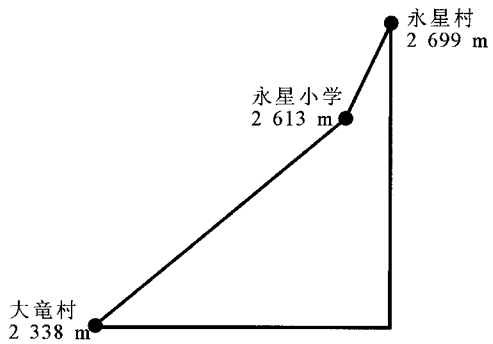
1 仪器和资料

截至8月11日共获取地震记录172个(516条)，$M_L \geqslant$ 3.0的地震48个，最大震级Ml4.4，最大加速度值65.9 gal。

永星台阵的平面图及垂直剖面如图1所示。大竜村台海拔2 338 m，属基岩台址，距永星小学台约2.5 km，垂直高差为275 m；永星小学台海拔2 613 m，为土层台址，距永星村台约120 m，垂直高差为86 m；永星村台w海拔2 669 m，属土层台址。



(a) 台阵平面布置



(b) 台阵垂直分布

图1 永星台阵布设示意图

Fig. 1 Layout dingran of strong motion array near the Yongxing village

本次观测所使用的流动强震动记录仪器的型号及主要参数指标见表1。

表1 K2强震动仪参数

Table 1 Parameters of K2 strong motion recorder

项目	技术指标
通道数及传感器制式	美国生产K2型强震动记录仪,内置三分量传感器
显示记录信道	EW向,NS向,垂直向
满量程输入	±2.5V;单端输入
频率响应	0~50 Hz
采样率	200 sps,可程控
数据通信	GPRS无线通讯
功耗	小于3W(等待记录状态)
环境温度	-20 ℃~+70 ℃
灵敏度	1.25 V/G

我们从永星台阵的强余震观测资料中选取震级较大的余震记录进行分析。其中8月8日岷县M_L3.8地震最大,着重分析此次观测结果。

2 地面峰值加速度记录和处理

地震现场数据回收后,我们进行了初步处理,分别读取各个台站的地表最大加速度值(表2)。可以看出,最大加速度值随震中距的增大而衰减迅速,距离最近的是大竜村台(基岩台址),获取的加速度记录NS向最大;另外两个分向也大于较远的两个流动台的记录。图2是地表加速度原始记录波形。

表2 M_L3.8余震各测点观测的地表最大加速度

Table 2 The peak ground acceleration caused by M_L3.8 aftershock at three stations in the array

地点	震中距/km	经度/(°)	纬度/(°)	高程/m	加速度/(cm·s^{-2})	地基
永星村	19.3	104.16	34.51	2699	30.1 37.1 43.9	土层
永星小学	18.0	104.15	34.50	2613	29.7 21.8 32.9	土层
大竜村	16.7	104.13	34.49	2338	34.3 65.9 46.6	基岩

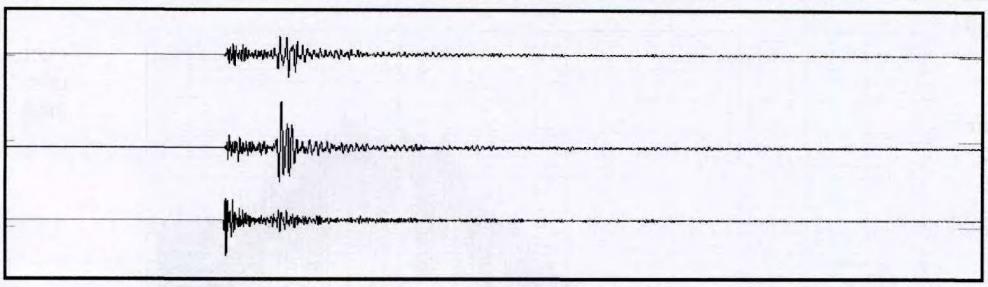
由于观测地区的黄土覆盖层较薄,土质松软,而黄土对高频成分的吸收作用不可忽视,因此永星村台、永星小学台这两个台的地震加速度记录不能与大竜村台的记录直接比较,应该进一步对各道记录进行频谱分析。为了进一步探讨地形对于永星台阵各个测点观测值的影响,我们进一步扩大资料筛选范围,取了大于等于M_L2.5以上的4次地震记录资料,分别量取各个台站的地表最大加速度值(表3)。从M_L3.8地震的记录结果可知,在近场情况下地表最大加速度对震中距十分敏感,由于每个台站相对于各次地震的震中距不同,所以无法直接对比不同地形对于地表加速度的影响。

我们将观测记录进行傅里叶分析,统计其优势频率,图3展示了部分典型记录的傅里叶谱。分析结果表明:大竜村台的优势频率为5.2 Hz;永星村台的优势频率为4.1 Hz;永星小学台的优势频率为5.3 Hz,注意到位于山脚下的大竜村台测点为基岩,加速度记录的优势频率自然较高,而位于山顶的永星村台是黄土地基,但是此地的加速度记录的优势频率明显高于山腰记录,几乎与基岩台基的优势频率相当。宏观调查也表明:低频率、高烈度对于房屋的破坏力更大。

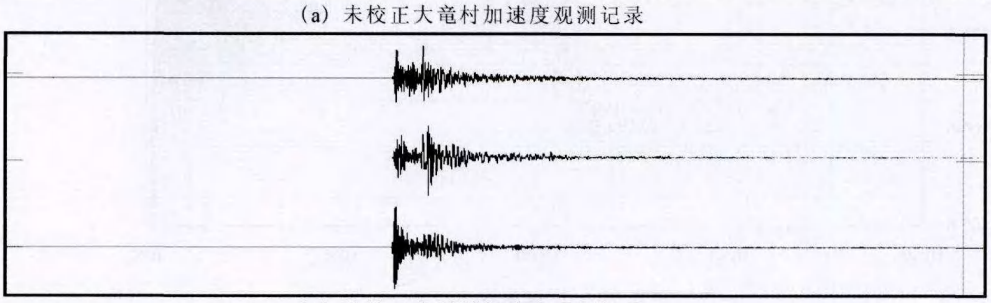
表3 余震强震动加速度记录(M_L≥2.5)

Table 3 Strong motion acceleration records ($M_L \geq 2.5$) for strongeroftershocks

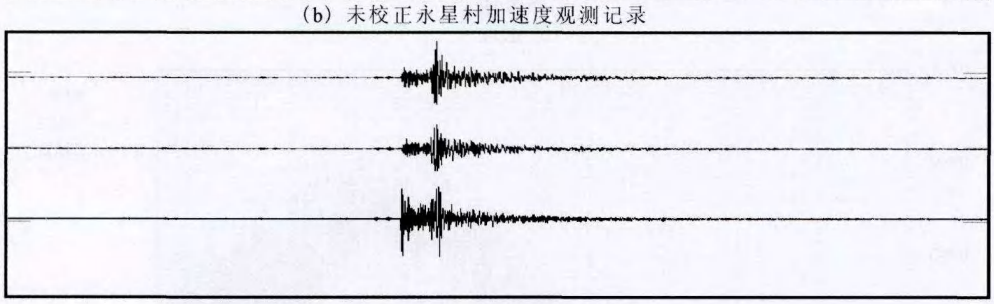
时间	震级/M_L	大竜村/(cm·s^{-2})			永星小学/(cm·s^{-2})			永星村/(cm·s^{-2})		
2013-08-02	2.5				14.3	11.4	12.5	14.3	27.8	17.6
2013-08-03	2.8	15.0	13.0	10.3	5.8	4.0	6.1	7.4	10.6	10.8
2013-08-07	2.6	3.8	5.6	5.3	3.5	2.8	3.0	4.2	4.3	2.7
2013-08-11	2.5	19.8	12.3	15.9				27.9	22.7	20.2



(a) 未校正大竜村加速度观测记录



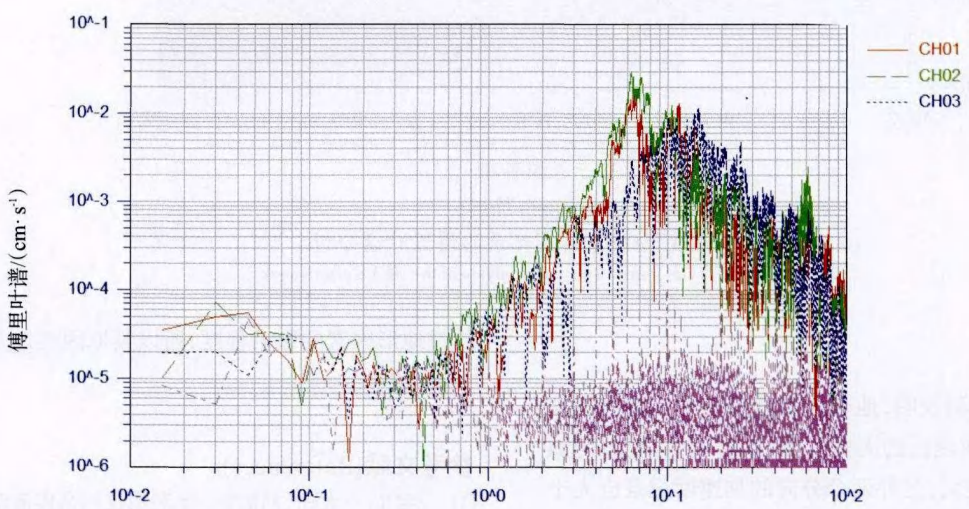
(b) 未校正永星村加速度观测记录



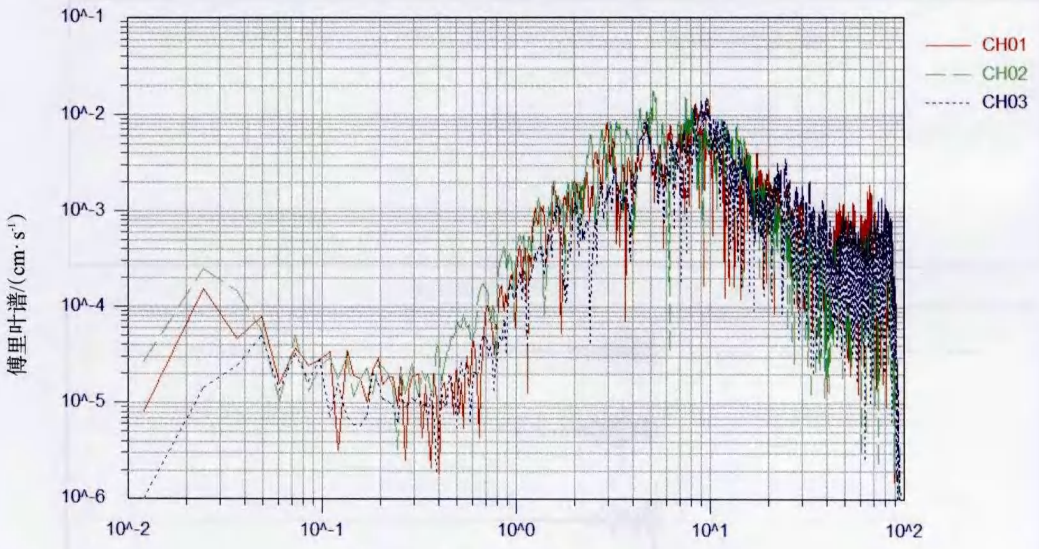
(c) 未校正永星小学加速度观测记录

图2 各台站记录的 M_L3.8余震未校正

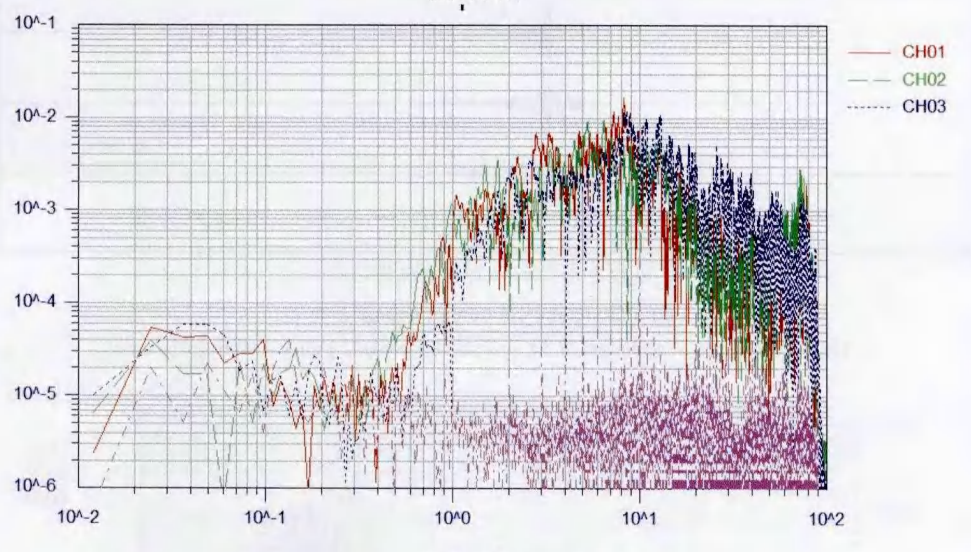
Fig.2 Uncorrected waveforms of M_L3.8 after shock recorded by three stations in the array



(a) 大竜村



(b) 永兴村



(c)永兴小学

图3 M_L3.8余震记录的傅里叶谱分析

Fig. 3 The fourier spectral analysis of the M_L3.8 after shock

3 结论

*M*3.8地震观测表明,地表加速度值随震中距的增大而迅速衰减,距离最近的大竜村台(基岩台址)获取的加速度记录NS向最大,另外两个分向的加速度记录也大于较远的两个流动台的记录。基岩台NS向比垂直向要大,和这次地震的震源机制(逆冲兼走滑)相关。地形影响依然存在:位于山顶的永星村台观测记录的傅里叶谱明显高于山腰的记录,地表最大加速度值也稍高于山腰观测。由于地形相差不够大,规律性不太明显。本次观测结果和以往在孤立山峰的观测情况略有不同,一是记录的地震震级偏小,二是观测距离偏近,震中距的影响可能超过地形因素的影响程度,所以其原因更加复杂,有待进一步研究。

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