Engineering Geology 183 (2014) 193–207

Contents lists available at ScienceDirect

Engineering Geology

journal homepage: www.elsevier.com/locate/enggeo

Evidence of hillslope directional amplification from accelerometer recordings at Qiaozhuang (Sichuan — China)

Yonghong Luo [a,*], Vincenzo Del Gaudio [b], Runqiu Huang [a], Yunsheng Wang [a], Janusz Wasowski [c]

[a] State Key Laboratory of Geo-Hazard Prevention and Geo-Environment Protection, Chengdu University of Technology, Chengdu 610059, China
[b] Dipartimento di Geologia e Geofisica, Universita degli Studi di Bari "Aldo Moro", via E. Orabona, 4-70125 Bari, Italy
[c] Consiglio Nazionale delle Ricerche, Istituto di Ricerca per la Protezione Idrogeologica, Via G. Amendola, 122-70126 Bari, Italy

ARTICLE INFO

Article history:
Received 14 April 2014
Received in revised form 6 October 2014
Accepted 9 October 2014
Available online 24 October 2014

Keywords:
2008 Wenchuan earthquake
Aftershocks
Directivity
Topographic amplification
Arias intensity
HVSR

ABSTRACT

This work reports the results of an accelerometer monitoring aimed at revealing the seismic response of hillslopes in the town of Qiaozhuang, in Qingchuan County, near the north-eastern end of the fault ruptured during the 2008 Mw 7.9 Wenchuan earthquake in Sichuan Province. Serious damage and slope failures were induced by this earthquake in the town center and on the hills in the peri-urban zone. This suggested the possible occurrence of amplification phenomena. Five accelerometer stations were emplaced at two topographic reliefs to investigate their response to ground motion during the last part of the Wenchuan seismic sequence. About 50 aftershocks were recorded, whose magnitude (M_L) varied between 1.2 and 5.5 and epicentral distance ranged from a few to 90 km. The accelerometer records provided evidence of directional amplification, which was investigated by analyzing the polar diagrams of normalized Arias intensity (Ia) and the horizontal to vertical spectral ratios (HVSR). Evidence of the anisotropic dynamic response and site specific resonance frequencies was obtained for both topographic reliefs.

However, the ground shaking maxima orientations differed depending on the local geological setting: in one case they were transversal and in the other case sub-parallel to the relief elongation.

No preferential direction of maximum shaking was observed at the site in the valley. Furthermore, evidence of resonance was derived from the calculation of spectral ratio between the sites on the slope and those at the foot of the hills. The resonance was more pronounced at higher elevations, which suggested a possible occurrence of topographic amplification. Resonance frequencies were lower (3–5 Hz) on the smaller hill consisting of subvertically layered phyllites and higher (up to 7 Hz) on the larger hill made mainly of limestones, whereas an opposite relation between resonance frequency and hill size could be expected from a purely topographic effect. This and the presence of amplification factors larger than 2 suggest that, in addition to topographic effects, local geology also played a significant role in differentiating the site response.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

At 14:28 of May 12th, 2008, a Ms 8.0 earthquake occurred in the Wenchuan county, Sichuan province, western China, with the epicenter located near Yingxiu town. This event led to tremendous casualties and property loss, a significant percentage of which were caused by the triggering of tens of thousands of landslides (Gorum et al., 2011). The interpretation of remote sensing data and field investigations showed that extensive rock slope failures and rock shattering often originated at the mountain tops or at slope convexities (Huang and Li, 2008; Xu and Huang, 2008; Wang et al., 2009). The concentration of source areas near the mountain ridge crests (Figure 1) suggests that seismically induced slope failures were favored by topographic amplification of ground shaking.

Several published case studies provided instrumental evidence of anisotropic amplifications affecting the top of the reliefs, often with shaking maxima oriented transversally to relief elongation. Such phenomena were observed on the Kagel Mountain and the Josephine Peak in California (Davis and West, 1973), in the mountains of the Appalachian chain in Tennessee and Virginia (Griffiths and Bollinger, 1979), on the hills in the area of Viña del Mar in Chile (Celebi, 1987), in the mountainous area hit by the 1989 Loma Prieta earthquake (Hartzell et al., 1994) and on the Wenxian hill (Gansu, China) where aftershocks of 2008 Wenchuan earthquake were recorded by a temporary array (Lu et al., 2011). The amplification phenomena were generally related to topographic effects and, in some cases, were invoked to explain the anomalous (high) concentration of slope failures observed near ridge crests (e.g. seismically triggered rock falls in Pacoima Canyon, Harp and Jibson, 2002; landslides triggered in the Pacoima Canyon, California

* Corresponding author.
E-mail addresses: luoyonghong2012@cdut.cn (Y. Luo), delga@geo.uniba.it (V. Del Gaudio), hrq@cdut.edu.cn (R. Huang).

http://dx.doi.org/10.1016/j.enggeo.2014.10.015
0013-7952/© 2014 Elsevier B.V. All rights reserved.

Fig. 1. Example of slope failures triggered by the Wenchuan earthquake. Note concentration of source areas along ridge crests. After Luo et al. (2013).

by the 1994 Mw = 6.7 Northridge earthquake, Sepulveda et al., 2005). However, the numerical modeling of relief dynamic response, though capable to account for the observed resonance frequencies, generally resulted in a considerable underestimate of ground motion in comparison to instrumental observations (Chiu and Huang, 1992; Bouchon and Barker, 1996; Spudich et al., 1996; Pischiutta et al., 2010). Therefore, amplifications affecting the top of reliefs can hardly be attributed to a purely topographic effect, especially when amplification factors are larger than 2. In such cases, the local geological conditions could be responsible for a considerable enhancement of site amplification. This and the scarcity of accelerometer monitoring data from slope sites (Wasowski et al., 2011) indicates that further research efforts are needed to improve our understanding of slope dynamic response.

The area damaged by the 2008 Wenchuan event include the Qingchuan County which is located more than 300 km away from the epicenter, near the north-eastern tip of the fault that ruptured during the earthquake (Figure 2). Seismic ground motion not only induced extensive damage to infrastructure located on the alluvial terrace deposits in the Qiaozhuang River valley, but also slope failures on the hills in the urban periphery of Qiaozhuang town, which is the urban center of the Qingchuan County. In particular, field investigation revealed that the upper parts of the Weigan hill, Mount Dong and Mount Shizi were severely shattered (Figure 3) and locally gave rise to rock falls. Since these phenomena were mainly observed near the hilltops, the influence of topography amplification was suspected.

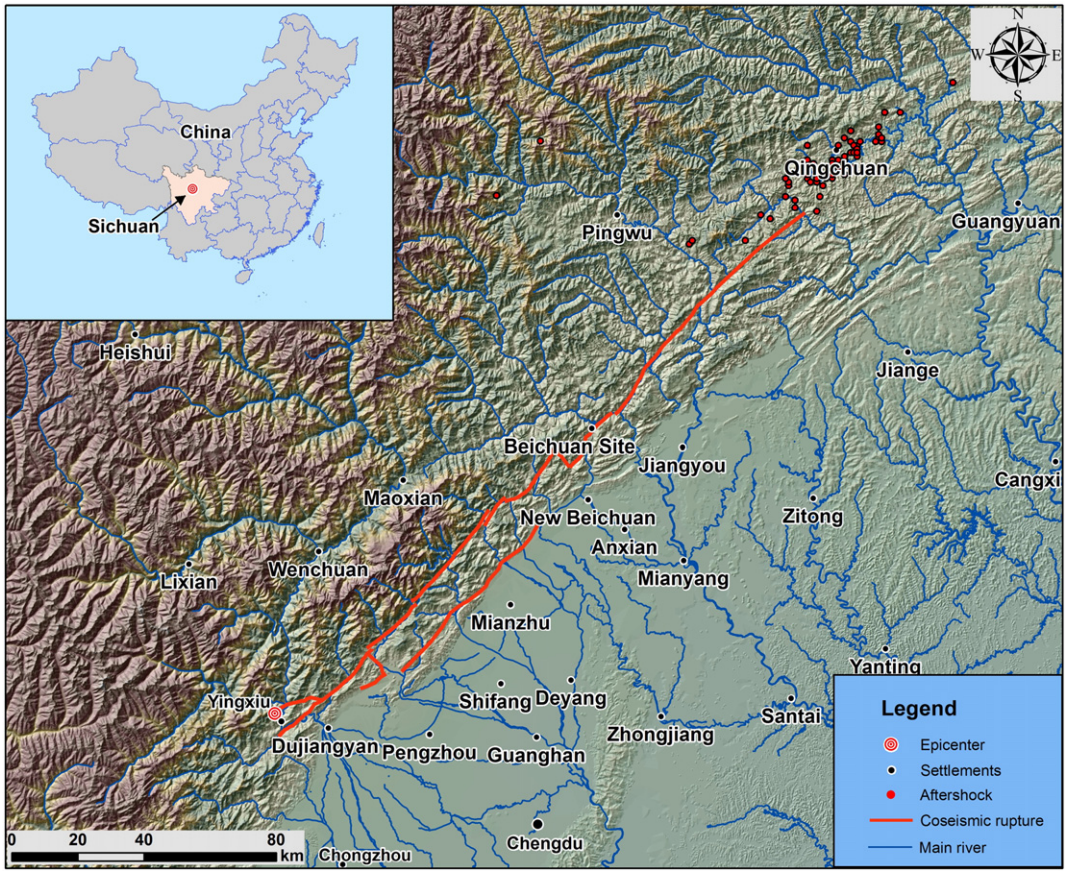

Fig. 2. Geographic locations of the region hit by the 2008 Wenchuan earthquake and of the Qingchuan county study area, including the epicenters of aftershocks recorded by the accelerometer monitoring stations at Qiaozhuang.

Download English Version:

https://daneshyari.com/en/article/4743589

Download Persian Version:

https://daneshyari.com/article/4743589

Daneshyari.com