Strong motions and engineering structure performances in recent major earthquakes

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In recent years, a series of major earthquakes occurred, which resulted in considerable engineering damage and collapse, triggered heavy geological hazards, and caused extremely high casualties and huge property and economic loss. The earthquakes include the 1994 Northridge earthquake ($M6.8$), the 1995 Kobe earthquake ($M6.8$), the 1999 Izmit earthquake ($M7.6$), the 1999 Jiji (Chi-Chi) earthquake ($M7.6$), the 2005 northern Pakistan earthquake ($M7.6$), the 2008 Wenchuan earthquake ($M8.0$) and the 2010 Haiti earthquake ($M7.0$). Some villages, towns and even cities were devastated in the earthquakes, especially in the 2005 northern Pakistan earthquake, the 2008 Wenchuan earthquake and the 2010 Haiti earthquake.

The earthquakes occurring in recent years have left abundant and complex earthquake phenomena that merit our further consideration. These phenomena give inspiration to and provide the ground for the development of seismology and earthquake engineering researches. It becomes research objective to probe into what kinds of new earthquake phenomena and inspiration can be provided for future research work and disaster prevention. In the Northridge earthquake, Jiji (Chi-Chi) earthquake and Wenchuan earthquake, there are not only many valuable data of engineering damages collected but also numerous data of ground motion and structural response recorded. The data of strong motion records are important to seismology and earthquake engineering researches. Therefore, researchers have paid much more attention to the study on strong motion records and the relation of the earthquake phenomena and ground motion in recent years.

Because an extensive strong motion instrumentation program in Taiwan was completed by CWB in 1996, over 30 000 digital strong motion records were obtained

from the Jiji (Chi-Chi) earthquake and thousands of its aftershocks, in which there are many near-fault records from over 60 recording sites within 20 km of the fault ruptures (Lee et al, 2001). At that time, these records formed the largest set of strong motion data recorded from a major earthquake since strong motion seismology studies began in the 1930s. After the Jiji (Chi-Chi) earthquake, another event is the Wenchuan earthquake which made the number of strong motion records remarkably increase. During the Wenchuan earthquake, the National Strong Motion Observation Network System (NSMONS) of China, which entered formal operation only two months before the earthquake, obtained 1 350 components of digital strong motion records from the main shock, including records from 437 free-field stations, one array for topographic effect observation, and two arrays for structural response observation (Li et al, 2008a, b; Lu and Li, 2008). In these stations, 228 stations are located in the range of surface rupture distance within 500 km, 31 stations within 100 km, and two stations within 10 km. After the main shock, 59 mobile instruments were quickly deployed to record ground motions and structural responses from strong aftershocks (Li, 2009a). 15 903 components of digital strong motion records were obtained from 949 aftershocks, in which 9 750 components were recorded by mobile instruments (Li, 2009a, b).

After the Jiji (Chi-Chi) earthquake, the research is rapidly progressed on the near-fault characteristics of ground motions and their effects on the modes as well as degrees of engineering structure damages. It is found that the near-fault characteristics of ground motions, such as the large peak vertical acceleration, large velocity pulse, long-period components and permanent displacement, which are closely related to the earthquake fault type, parameters of fault rupture and site condition, play important roles in affecting the response and damage of engineering structures. The Wenchuan earthquake will enhance the relative researches. It is expected to

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reveal the failure mechanism of engineering structures and reasonably explain the disaster phenomena by the study of earthquake resistant behavior of engineering structures and characteristics of ground motions.

The preliminary study on strong motion records clearly demonstrates that some characteristics of ground motion from the Wenchuan earthquake, especially of near-fault ground motion, such as the large peak vertical acceleration, fault rupture propagation or directivity effect, and hanging wall/footwall effect (Li et al, 2008a, b). However, some different characteristics are also shown between the ground motions from the Wenchuan earthquake and Jiji (Chi-Chi) earthquake. The large velocity pulse, rich long-period component and large permanent displacement, which are found in ground motion from the Jiji (Chi-Chi) earthquake, are not clear in ground motion from the Wenchuan earthquake, especially the long-period component is much less than that from the Jiji (Chi-Chi) earthquake. On the other hand, the duration of near-fault strong motion records is much longer from the Wenchuan earthquake than that from the Jiji (Chi-Chi) earthquake, and multi-segment of strong motion time histories clearly appeared in many records.

A great deal of research work was done on damage investigation and performance analysis of engineering structures in the Wenchuan earthquake (China Academy of Building Research, 2008; Yuan and Sun, 2008). The effects of fault rupture direction, topography and soil condition are clear on the disaster distribution in the Wenchuan earthquake. It seems that the damage of long-period structures such as chimney and water tower is less than that of short period structures such as multi-storey building in near-fault area, e.g., Hanwang, Shifang and Dujiangyan. There is no evidence for the performance of long-period buildings due to lack of high-rise buildings in near-fault area. The phenomenon of less damage of long-period structures was also found in the northern Pakistan earthquake (Li et al, 2007). Contrary to the Wenchuan earthquake, the damage of high-rise buildings was serious in the Jiji (Chi-Chi) earthquake (Tsai et al, 2000). Considering the analysis results of ground motion, it seems that the phenomenon is related to the difference in long-period components of ground motions in Wenchuan and Jiji (Chi-Chi) earthquakes. The investigation of damages and behaviors of dams shows that the large dams were only slightly damaged in the near-fault area although many small dams were destroyed by the Wenchuan earthquake (Chen, 2009). Author thinks that there are two possible

reasons to lead the damage status. The first may be the high earthquake resistant capability, and the other should be the less long-period component of ground motion in the Wenchuan earthquake. Because the natural vibration periods of those large dams are over 0.4 s, the response of the dams should be smaller under ground motion of the Wenchuan earthquake than under the ground motion with rich long-period component like that from the Jiji (Chi-Chi) earthquake.

There are 13 papers in this special issue. The papers focus on the analysis of strong motions and engineering structure performances on the basis of data of engineering damage investigation and strong motion recording from recent major earthquakes such as the Northridge earthquake, Jiji (Chi-Chi) earthquake and Wenchuan earthquake. Lu D W et al established the ground motion attenuation relations of the Wenchuan earthquake based on strong motion records. Wu et al proposed a set of response spectral values of near-source ground motion for small and moderate earthquakes. Wen R Z et al analyzed the site classification method including the horizontal-to-vertical spectral ratio method and the response spectral shapes method on the basis of strong motion records of the Wenchuan earthquake and detailed borehole data. Liang J W et al, Liu Z X et al, and Ba Z N et al respectively presented analysis methods for scattering and diffraction of incident plane SH, P waves for several simplified site models, and discussed effects of site parameters on scattering and diffraction of incident waves. Zhou G L et al analyzed the topographic effects on ground motion, and furthermore evaluated the topographic effects on long span bridge response. Davis C A et al simulated the response of two concrete lined channels in the Northridge earthquake, and found that the channel liners may be damaged from both transient motion and permanent ground movement. Liu J B et al proposed a seismic fragility analysis method of the composite frame structure and obtained fragility curves, in which the uncertainties in structure itself and ground motion are considered. Li J et al investigated the effect of surface wave on shallow buried utility tunnel and analyzed effect of soil-structure interface and the buried depth of underground structure. Che W et al and Yang F et al analyzed the time-frequency response spectrum of the rotational motions and discussed the torsional phenomena in the Wenchuan earthquake. Zhao L et al studied the influences of the rupture mode, thickness and rigidity of overlying soil on the response of buried pipeline.

Authors wish that their research results are of benefit to understanding the characteristics of ground motions and the damage mechanism of engineering structures in large earthquakes such as the Jiji (Chi-Chi) earthquake and Wenchuan earthquake.

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