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Seismic wave propagation damage caused by the 1999 Chi-Chi, Taiwan earthquake: I. Repeating earthquakes observation

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Observation of three quasi-periodic M 3.8~4.6 repeating earthquake sequences in eastern Taiwan from 1991 to 2007 reveals a unique temporal and spatial variation in seismic wave character associated with the 1999 Mw 7.6 Chi-Chi earthquakes in central Taiwan. The repeating events occurred after the time of Chi-Chi event reveal late-arriving phases and notable change in seismic wave character of S-wave coda. The drop of the cross correlation coefficients (ccc) between the repeating earthquake pair is significant in high-frequency wavefield. At station SSLB for example, the drop of the ccc ranges from 0.99 to 0.95 and 0.99 to 0.88 in 1 Hz and 4 Hz, respectively. Using moving window cross correlation technique, we identify delay of phases in the S-wave coda to be as large as 50 ms, corresponding to a 1% velocity decrease averaged over propagation path. Such velocity reduction is commonly considered as a result of near surface damage. However, the observed changes of seismic wave character are not localized to where the earthquake induced surface displacement or ground acceleration were larger nor where the unconsolidated deposits are located. Instead, it is found in widely distributed stations close to the Chi-Chi epicenter by a 50x80 km² area. The near surface physical damage caused by strong shaking during the earthquake, therefore, cannot explain the change in seismic waveform character alone. The damaged zone over deep fault plane, or a combination of surface and fault zone damage may contribute to the observed Chi-Chi effect. Time delayed arrivals and decreased waveform similarity are gradually recovering to normal level as time passes, indicating a slow healing of physical damage after the Chi-Chi earthquake, though until 2007 it has not returned perfectly to the pre-mainshock level.

Keywords: repeating earthquake sequence, fault healing, Chi-Chi earthquake