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Depth-dependent coseismic groundwater level changes by seismic ground motion of the 1999 Chi-Chi earthquake, Tiwan

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The coseismic water level change (Cw) has been reported (Montgomery and Manga, 2003; Koizumi, 2013). One of the causes of the Cw is crustal displacement (static strain change and vertical displacement etc.), and seismic ground motion(dynamic volumetric strain change and hydraulic conductivity change etc.)(Lee *et al*., 2002; Lai *et al*., 2004; Wang *et al*., 2001). The static strain change has been assumed as one of the main factor of the water level change from the comparison of water level change with static strain change in the earthquakes. However, the relation between water level change and static strain change doesn't correspond clearly. Although the dynamic strain change by the ground motion would be more effective to the cause of Cw, the effect has not been known yet.

The Chi-Chi earthquake (Mw7.6) occurred in central Taiwan at 1:47 (local time) on September 21, 1999. The earthquake was the largest event which occurred recently in the inland of Taiwan. Since the both networks of strong motion seismometer (Lee *et al*, 1999) and water level monitoring system (Koizumi, 2001) are distributed densely around the source fault of the Chi-Chi earthquake, good seismic waveform and the data of Cw has been obtained.

For the previous study of Cw in the Chi-Chi earthquake, Wang *et al*.(2003) has been analyzed the relationship between Cw and seismic ground motion from the point of view of liquefaction at the shallow groundwater in the alluvial plain part. They showed that there is correlation between the spectrum velocity or acceleration and water level. However, they did not account much for the effects of the permeability or other characteristics in each aquifer although they analyzed the Cw of all wells at once. Since the hydrogeological conditions effects to the occurrence of liquefaction similar to the effect of ground motion, the effect for the hydrogeological conditions, that is the geological characteristics and permeability of aquifer in confined aquifer or unconfined aquifer, must be investigated.

We divided the aquifer to similar hydrogeological categories and examined the Cw response by the ground motion in each aquifer. We put target groundwater of two aquifer, the shallow aquifer 1(unconfined aquifer)and underlying aquifer 2(confined aquifer), and investigated whether there are the different character in those. I measured the degree of Cw. Therefore the wells observed Cw were 84 wells, fall wells were 14 wells in these wells. I used the observation wells with water level rises in the alluvial plain part, because the mechanism of water level change for water level fall is different. We investigated the relationship spectral response of seismic wave and groundwater level change, because spectral response can read the effect to the ground in comparison spectrum of normal. We calculated the response of Cw against the frequency of 1 Hz (high-frequency) and 0.1 Hz (low-frequency) to evaluate the groundwater level change as a function of frequency. We calculated the acceleration, velocity, and displacement spectral response of vertical, horizontal, and 3 components from acceleration waveform data. I investigated the correlation coefficient between spectrum and Cw in each aquifer. The result frequency band in those show different response was obtained. Correlation between the response spectrum and water level change in the high-frequency side (1 Hz) was higher in the aquifer considered unconfined aquifer, but the correlation in low-frequency side (0.1 Hz) was higher in the aquifer considered confined aquifer. In common to both aquifer, correlation between hydraulic conductivity and water level change showed strong positive correlation.

Keywords: Groundwater level changes, The 1999 Chi-Chi earthquake, Taiwan, Seismic ground motion