論文名稱：利用時頻分析技術檢視土壤非線性反應　　頁數：128

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論文提要內容：

在地震觀測上，利用雙站頻譜比法得知強、弱震之共振主頻變化以及壓抑放大現象可以判斷土壤的非線性反應。而本篇文章則是利用時頻分析技術，以共振主頻隨時間之變化來探討局部地區土層之場址效應，尤其是強震與弱震間土壤共振主頻之差異。

本研究使用台灣羅東 LSST 井下陣列於 1985~1987 年間所收到之強地動資料，分別挑選強震（最大加速度值大於 150gal）、弱震（最大加速度值小於 80gal）資料，以及日本神戶港 Port Island 井下陣列於 1995 年發生的 Hyogo-ken Nanbu 主震(最大加速度值為 555gal）和餘震資料，及 1994 年弱震（最大加速度值小於 15gal）資料。利用短時傅氏轉換（Short Time Fourier Transform）、小波分析（Wavelet Analysis）及雙站頻譜比法（Spectral Ratio Method）來探討區域土壤共振主頻隨時間之變化。並利用前人之研究結果得知羅東 LSST 區域強、弱震之共振主頻分別約為 2Hz 及 3Hz 附近，藉此評估本研究方法能否觀察到土壤受強震作用之時序影響，由線性到非線性反應、再由非線性到線性反應其主頻變化之可行性。

在 LSST 井下陣列研究結果中，本研究將各個時間窗格之頻譜比值都做了正規化之動作以突顯共振主頻隨時間之變化。利用此法分析弱震之結果，從地震發生到結束可以清楚地看到共振主頻隨時間之變化均在 3Hz 附近，為一定值，驗證了土壤在弱震作用下為線性反應。而在強震之反應上可以清楚地看到震波在一開始共振主頻落在 3Hz，與弱震之共振主頻相同，此時土壤為線性反應；在剪力波進來後，共振主頻掉至 2Hz 以下，此時土壤出現非線性反應；在剪力波通過後，共振主頻即回復至 2.5~3Hz，此時土壤特性恢復為與弱震相同之線性反應。

在日本 Port Island 井下陣列研究結果中，強震之共振主頻在剪力波過後之值均在 2Hz 以下，並未回復至弱震之共振主頻 4Hz，這驗證了前人之研究結果，此地震在此區域產生了液化現象，使土壤之本質與特性不復在，故共振主頻並不會回復至土壤線性反應時之主頻值。

本研究亦初步探討使用近年來廣泛研究與應用之 HHT（Hilbert Huang Transform）方法來分析 LSST 井下陣列地震記錄，其結果與上述兩方法所獲得的結果並不相同，在弱震反應上，共振主頻值並不為一定值，呈現上下跳動外其值大都偏低；在強震反應上，並無發現共震主頻在剪力波進來前後有明顯之差異。

整體而言，利用時頻分析技術確實可以觀察到局部土壤的非線性反應隨時間的變化，而如何運用 HHT 方法分析時變的土壤特性需更進一步深入之研究。

Recognition of nonlinear site response applying the time-frequency analysis method

ABSTRACT

The predominant frequency decrease and de-amplification of strong motion spectra at a soil site are recognized as occurring nonlinear site effects. In this study, the strong and weak motion events recorded by the LSST borehole array in Taiwan and the Port Island borehole array in Japan are analyzed by spectral ratio method with the Short Time Fourier Transform (STFT) and Wavelet Analysis. The spectral ratios of surface to borehole sites are calculated to analyze the predominant frequency variations with time. We knew the predominant frequency of the week motion respectively is 2-3 Hz and 3-4 Hz by the previous results for the LSST array and the Port Island array. Then we estimate the practicability of the proposed methods to show the soil nonlinear response during the time history of the strong motion events.

For the LSST array in Taiwan, the predominant frequency varies with time from beginning to end of the week motion is about 3 Hz obviously using this method and it demonstrated that the soil response is linear on the weak motion. On the other situation, we can see the predominant frequency of the strong motion event is 3 Hz at the initial portion and it’s the same with the weak motion result so it shows linear soil response at this time period. Then the predominant frequency of the shear wave is decrease to 2 Hz during the strong motion portion, the findings indicate that the soil response is nonlinear. At the later portion after the strong motion portion, the predominant frequency returns to 2.5-3 Hz immediately and the soil response recovers to linear condition.

In the result of Port Island array in Japan, the predominant frequency varies with time from beginning to end of the weak motion is about 3.5-4 Hz. On the case of 1995 Kobe earthquake, the predominant frequency after the shear wave is decreasing less than 2 Hz on the mainshock because the soil is liquefied. And 3 hours after the mainshock, the predominant frequency returns to about 3 Hz which is less than 3.5-4 Hz, and this shows the soil characteristic can’t return to the original situation due to the liquefaction effect.

In this study, spectral ratio method with the time-frequency analysis was used to observe the variations of predominant frequency with time on the strong motion event. Much remains to be done, then, but we anticipate that the same results will be generated by the HHT method to improve the resolution of the time and frequency domains.