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A Study on the Mechanism of Water Well Resonance Induced by Pre-earthquake Signals

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ABSTRACT

In this study, we analyze the physical mechanism of water well resonance induced by pre-earthquake signals. A weak pressure wave passing through the confined aquifer is considered as the incoming pre-earthquake signal. Since the porous skeleton is hard, this pressure wave is simply the limiting case of second kind of dilatational wave of poroelasticity. Because the driving signals of weak pre-earthquake pressure wave transmitting through confined aquifer are so weak that can hardly affect the solid skeleton we, believe a very possible reason for this is due to the effect of resonant amplification of free surface water waves in wells. The water inside the well is assumed to be incompressible, inviscid and irrotational while that outside the well is treated as porous-media fluid flow with rigid skeleton. The potential flow theory with small amplitude water wave and porous media flow following Darcy's law are adopted for waters inside and outside the well respectively. By using the regular perturbation expansion method based on a small gauge function k_0R (k_0 is the wavenumber, R is the well radius), the well-posed boundary-value-problem thus can be solved. It is found that the weak pre-earthquake longitudinal pressure wave is only a triggering mechanism for the resonance of transverse gravitational free surface water wave inside the well.

KEYWORDS: pre-earthquake signals; well; resonance; longitudinal wave; transverse waves.

INTRODUCTION

The problem of the response of groundwater induced by earthquake has been studied by many investigators. For example, Cooper et al. (1965) is a study on the response of well water to seismic waves, and Liu and Wen (1997) is the analysis of the long waves passing through aquifer. However, researches on the response of groundwater induced by weak pre-earthquake signals are rare.

There are evidences, indeed, that groundwater somehow is affected by very weak pre-earthquake signals. For example, one day before the drastic 921-earthquake at central Taiwan in 1999, pre-earthquake responses were observed in some water wells in Tsuo-Shui River water basin in central Taiwan. Because the driving signals of weak pre-earthquake pressure wave transmitting through confined aquifer are so weak that can hardly affect the solid skeleton we, believe a very possible reason for this is due to the effect of resonant amplification of free surface water waves in wells. Although unlike resonances driven by large energy such as Cooper et al. (1965) or conventional harbour resonance researches, the traditional resonance analyzing methods are still worth referring to for our present study.

In Cooper et al. (1965), the oscillation of water column in a well due to an incoming harmonic seismic wave is studied. This problem is similar to the well-known oscillating fluid in a U-tube of fluid mechanics (e.g. see Chapter 13 of Streeter and Wylie (1985)). This study is about the response of well water due to huge seismic wave but not weak pre-earthquake wave. Although the resonance phenomena is not discussed in Copper et al. (1965), the resonant effect of it can be easily obtained.

Harbour resonance is an important problem for harbour design. The famous " Merian's formula" is just the result of the resonant analysis of water wave which relates the unfavored harbour geometry to the designed wave. There are many investigations about harbour resonance, for example, McNown (1952), Mei (1989), etc. are theoretical studies, Chen and Mei (1974), Tsay and Liu (1983), etc. are numerical researches.

In this study, we'll refer to the aforementioned resonance studies and analyze the resonance of water in wells in response to weak pre-earthquake signal transmitting through confined aquifer. A weak pressure wave passing through the confined aquifer is considered as the incoming pre-earthquake signal. The water inside the well is assumed to be incompressible, inviscid and irrotational while that outside the well is treated as porous-media fluid flow with rigid skeleton. The potential flow theory with small amplitude water wave and porous media flow following Darcy's law are adopted for waters inside and outside the well respectively.

FORMULATION

Governing Equations of Fluid in Confined Aquifer

Based on Biot's theory of poroelasticity, for the skeleton of the porous aquifer being assumed rigid, and the water incompressible, the