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Ultrasonic Effects on Water Flow Through Porous Media

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This paper presents the results of laboratory tests conducted to investigate ultrasonically enhanced flow rates using specially designed and fabricated equations and equipment. The influencing factors (α_i) which indicated the effectiveness of ultrasound were verified for their effect on a soil matrix with flowing liquid. The test conditions involved various soil types, head losses and ultrasonic energies. Results revealed that ultrasound significantly enhanced flow rates; however, the degree of enhancement and values of the influencing factors varied over the test conditions.

INTRODUCTION

The behavior of a fluid's flow rate through porous media has been well known since Darcy (1856) formulated an empirical equation for the flow of water through sand. Subsequently, many investigators have studied the phenomenon of liquid flow through porous media. In 1950, some researchers observed a sharp change in the water level of a 50-m-deep well in Florida due to a nearby passing train and a remote earthquake. They reported the phenomenon as attibutable to the effects of stress waves on fluid flow through porous media. Later, in Daghestan, a large increase in oil production and renewed production from previously abandoned wells were observed after a 6.5 magnitude earthquake was reported. Since then, stress waves have been utilized in the petroleum industry to enhance oil recovery.

It is known that ultrasound can markedly influence the behaviors of fluid flow through porous structures. Fairbanks and Chen (1971) investigated the percolation of oil through sandstone at different oil temperatures in the presence of an acoustic field at 20-kHz frequency. They reported that percolation rates were increased due to sonication at all temperatures. Using a simple physical model of oil flow through glass capillary tubes, they demonstrated, based on the principle of force equilibrium, that the increased percolation rate due to sonication is primarily due to the reduced interfacial tension between capillary wall and oil. Based on the test results, they suggested using acoustic horns to enhance oil recovery from reservoirs.

Aarts et al. (1998) studied the mechanism of induced net flow by ultrasound. Poesio et al. (2002a and b) found that ultrasound has a significant effect on the pressure gradient and temperature of core samples at a constant liquid flow rate. They did not show a physical increase in the permeability of the flow rate of the pore liquid. However, the above informational items on ultrasonic applications in soil science are scarce and only at a conceptual stage. Nearly every available study focuses only on limited, specific conditions, without a systematic investigation of a broad spectrum of influencing factors. There is then no available methodology for evaluating the effectiveness of ultrasonic waves. Such a methodology is essential for the practical application of using stress waves to enhance fluid flow through porous media. It was with this objective in mind that this study was undertaken.

In this study, the influencing factors (α_i) which indicate the effectiveness of ultrasound were verified by the reconstructed permeability equation. Then, under various test conditions, changes in the flow rate and influencing factors from ultrasound excitation were investigated.

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KEY WORDS: Enhancement, flow rate, influencing factor, porous media, ultrasound.

LABORATORY EXPERIMENTS

Test Soils

The test soils were commercially available Joomoonjin sand, well-graded Granite residual soil SW, and poorly graded Granite residual soil SP, all very common in the Korean peninsula. Table 1 and Fig. 1 give the typical parameters and particle size distribution curves.

Test Apparatus

The test setup was composed of 4 parts: the test chamber, water reservoir, peristaltic pump, and sonicator. The test chamber was made of an acrylic cylinder with an inside diam of 5 cm and a height of 20 cm. Inlet and outlet tubes were installed in the upper part of the cylinder. A pump connected the inlet tube to a de-aired distilled water reservoir. The outlet tube was used to maintain a constant head by allowing the overflow of excess water. At the

	Joomoonjin sand	Granite soil SW	Granite soil SP
Specific gravity (G_s)	2.54	2.57	2.57
Adjusted void ratio (e)	0.6	0.6	0.6
Effective grain size (D_{10})	0.29 mm	0.31 mm	0.21 mm
Uniformity coefficient (C_u)	1.79	5.32	2.31
Unified soil classification	SP	SW	SP

Table 1 Properties of test soils