Influence of Vibration on Water Flow through Saturated Porous Media Using PVDF (polyvinylidence fluoride) Film

Ji-Ho Park, Tien Trung Hoang, Young-Uk Kim
Dept. Civil & Environmental *Engineering, Myongji University. South Korea*
E-mail: trunghoang86@gmail.com

ABSTRACT
This paper presents the results of laboratory tests conducted to investigate ultrasonically enhanced water flow rates using vibration energy of polyvinylidene fluoride PVDF film. Vibration is used widely in engineering, medicine and many aspects of daily life. One of the application is dewatering of saturated porous media was enhance using ultrasound. Vibrations were generated using PVDF Film with various frequencies 0 – 20 kHz and amplitude as the innovative technique. The test conditions involved various frequencies, amplitude and thickness of soils. The test results show that increasing wave energy and frequency can increase water removable from soil. This is one idea of soil remediation methods using flow by vibration.

RÉSUMÉ
Cet article présente la modélisation ainsi que les résultats des tests effectués pour étudier ultrasons qui renforcent le débit d'eau utilisant l'énergie des vibrations de fluorure de polyvinylidène PVDF film. La vibration est largement utilisée dans l'ingénierie, la médecine et de nombreux aspects de la vie quotidienne. Une des applications est l'assèchement de milieux poreux saturés ayant été renforcée par l'utilisation d'ultrasons. Les vibrations ont été générées en utilisant PVDF film avec différentes fréquences de 0 à 20 kHz et l'amplitude comme ceux de la technique innovante. Les conditions d'essai se composent de diverses fréquences, l'amplitude et l'épaisseur des sols. Les résultats des essais montrent que l'augmentation de l'énergie des vagues et de la fréquence peut augmenter d'eau amovible de terre. C'est une idée des méthodes de décontamination des sols utilisant des flux par les vibrations.

1 INTRODUCTION

The behavior of a fluid's flow rate through porous media has been well known since Darcy (1856) of saturated water flow through a homogeneous porous medium contained in a vertical column have provided the basis for the quantitative description of fluid flow in a wide variety of both natural and engineered porous medium environmental systems. Extrapolation of Darcy's original observations and conclusions has led to several commonly applied equations used to model flow in porous media. 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 attributable 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.

It is known that ultrasound can markedly influence the behaviors of fluid flow through porous structures. For instance, Chen investigated the influence of ultrasonic radiation (at a frequency of 20 kHz) on the flow of water oil through a stainless steel filter, on the flow of oil through porous sandstone samples he found that ultrasonic radiation increased the oil – flow rate by a factor of three. Although the ultrasonic energy heated the oil, and hence decreased its viscosity, he showed that only a part of the increase of the flow rate could have been caused by the viscosity decrease. The oil industry has shown great interest in the effects of ultrasound on the flow through a porous medium. The reason is that in production the oil flows due to a pressure gradient through a porous medium in the underground, the so-called reservoir, into a well. The effects on flow rates observed in experiments thus reveal that ultrasonic irradiation of the reservoir down-hole in a well is capable of increasing oil production.

The study of flow in saturated porous media is important in a wide range of applications including groundwater flow, exploitation of petroleum reservoirs, filter design, manufacture of petroleum composites, capillary circulation, chemical reactors, etc. In this study, we investigated an innovative technique for reducing the water content in sandy soils by using PVDF film (polyvinylidene fluoride). The principal purpose of this method is to accelerate the grains move and permutation; this process makes the water drains out easily. Vibrations are generated by using PVDF film with various frequencies and amplitude. This test result demonstrated that the vibrations can reduce water content effectively by using PVDF film.

2 LABORATORY EXPERIMENTS

2.1 Experimental Equipment and Measuring Instrumentation

The main equipment for the study consists of PVDF film, function generator (Tabor – 8020), and amplifier (EPA-104). Give the vibration, the PVDF film is a good material which can work well with the function generator at any frequency or voltage. Vibration is generated by using the PVDF film with various frequencies. This study investigates the effects of sound waves which are generated from PVDF film and confirms whether it can reduce water content in silly sands.

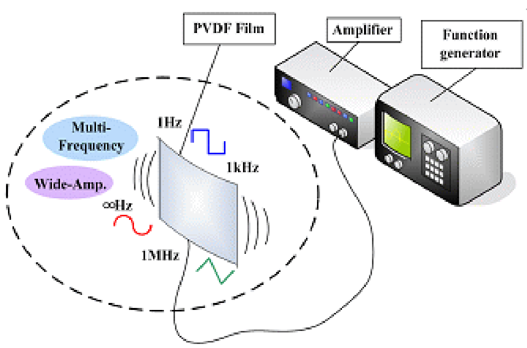

Figure. 1 PVDF system

Test procedures are as follows. We will do many tests in different conditions. The main equipment which will be used in this test have PVDF film, function generator and amplifier. And we also need prepare graduated cylinders, soil box, stopwatch and gravels.

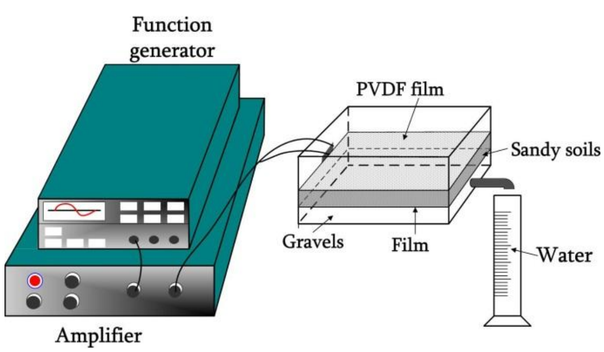

Figure. 2 Test set-up

At first, put the gravels into the soil box (a) and cover the pored film on the gravels (b). In order to avoid the sandy soils and gravels fix together, put a pored film between gravels and sandy soils is necessary. Second, put the sandy soils into the soil box (c). Use the graduated cylinder to measure a given volume of water and put the water into the soil box (d) until saturated, saturated ratio maybe obtained = 0.9- 0.95%. Remember the volume of water and calculate the initial water content. Later, when we need compare the test results, we need ensure that some conditions are same. Just started to put the water into soil box, there are some time to permeate. Because of for the fine sand, the hydraulic conductivity k is not large. Sometime later, until the soils saturated (e), the setting is nearly complete. After, in the case don't use the PVDF film, we only need to cover a panel on the sandy soils (f). Measure the rate of flow every five minutes.

The last step, apply vibration energy which contacts with PVDF film on the top of soils (g) and connect the PVDF film with function generator(h). And measure the rate of flow by using the other graduated cylinders every five minutes.

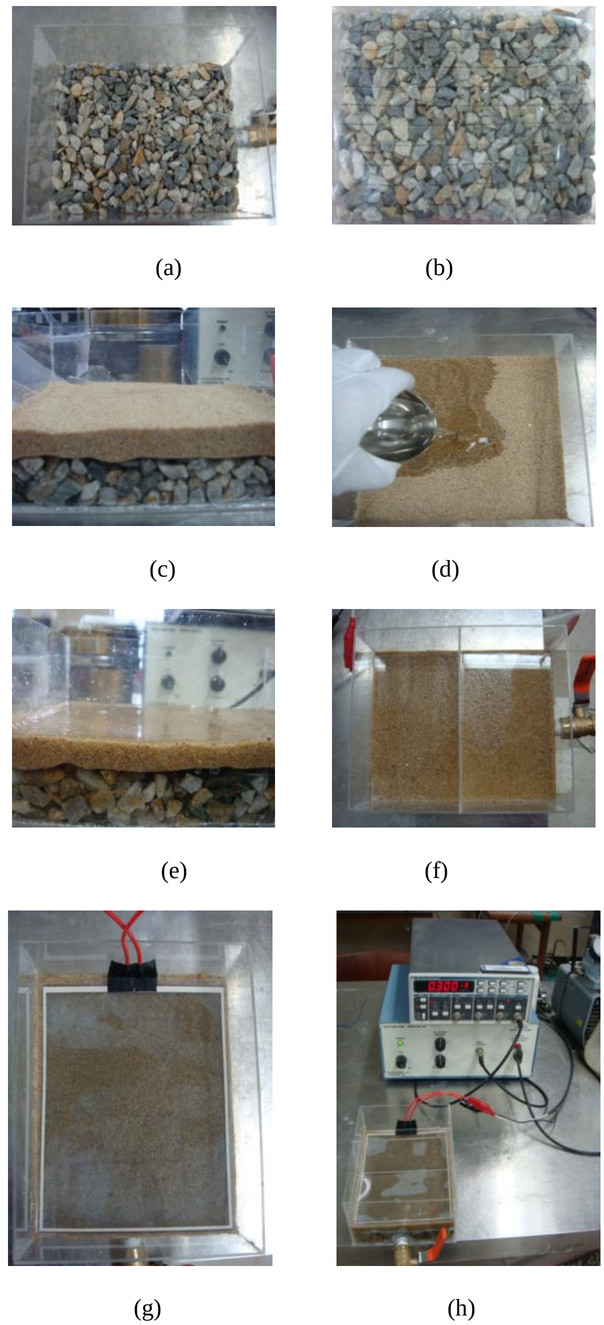

Figure. 3 Test procedures

In process of dewatering, nearby the drain hole and other places, the sandy soils were sunk. This is because of pressure. This process only can reduce the water content, but can't make the water drain out completely. When finish all the tests, calculate water content again and calculate the difference between using vibration and no-vibration.

2.2 Results and discussion

Every group of tests at least contains two tests which one is given vibration and the other one is not given vibration. With the different frequencies from PVDF film, observe and measure water outflow from soil box. This test includes three parts:

- With the same frequency and water content, we can observe the results with different amplitudes.
- With the same amplitude and water content, we can observe the results with different frequencies.
- Change the thickness of the soils in the same water content

2.2.1 Amplitude equals to 10v and change the frequency at 4,5,6, and 7 kHz

As shown in Fig. 4, we can see that there are difference between using vibration and no-vibration, especially at initial stage. When the frequency= 6 kHz in the same amplitude, the outflow is the largest and the difference between using vibration and no-vibration is the most obvious. When the frequency= 6 kHz, the effect is the best.

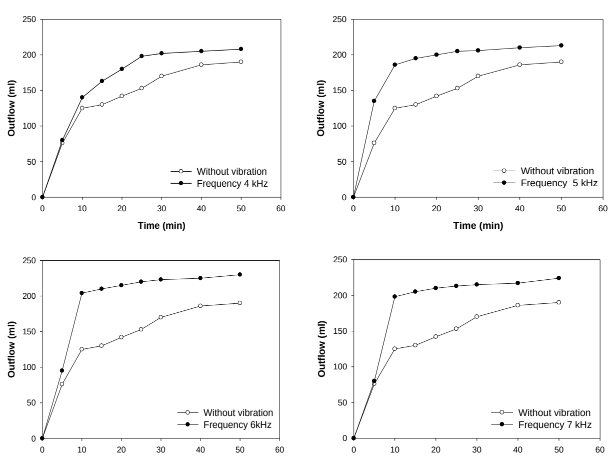

Figure.4. Outflow in different frequencies - amplitude 10V

Using vibration shorten much time which compare with not using vibration. For example, look at Fig. 4, when there are no vibrations, the final outflow is nearly 180ml at t=50min. But when using vibration, at t=10min, the outflow is already larger than no-vibration. This process shortens 40minutes. So we can say using PVDF film can accelerate the outflow and shorten the dewatering time. When finish a test, the final outflow is larger than without vibration

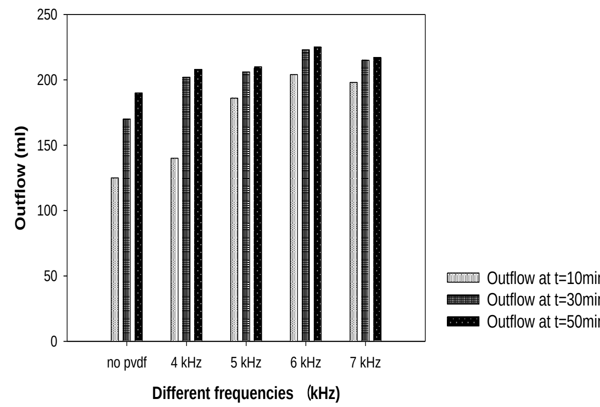

Figure.5. *Compare outflow in different time with same amplitude 10v*

Through Fig. 5, when t= 10min, the difference between using vibration and not using vibration is the most obvious. So we can say using PVDF film can accelerate the rate of outflow. At the initial time, the outflow is larger than at the later stage. And when the frequency= 6 kHz, the outflow is the largest

2.2.2 Amplitude equals to 15v and change the frequency at 0.3,0.4, 4 and 5 kHz

With the largest amplitude value 15v, the frequency at 0.3, 0.4, 4, and 5 kHz and the entire same conditions aforementioned test, the results are shown in Fig. 6.

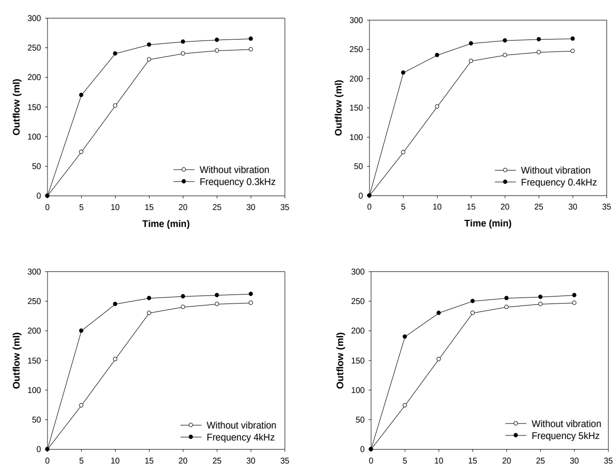

Figure.6. Outflow in different frequencies - amplitude 15V

Fig. 6 shows that the rate of outflow at the 0.3 kHz is faster than at the frequency=0.4 kHz. The last outflows are similar in the range of permitted errors. When the frequency=4 kHz, the rate of outflow is faster than the frequency=5 kHz. And the last outflows are similar in the range of permitted errors.

The final difference between using vibration and without vibration is not obvious. But at initial stage, the difference is very obvious. So we can say using PVDF film can accelerate the rate of outflow. There are not much difference between frequency=0.3 kHz and 0.4 kHz and frequency=4 kHz and 5 kHz, respectively.

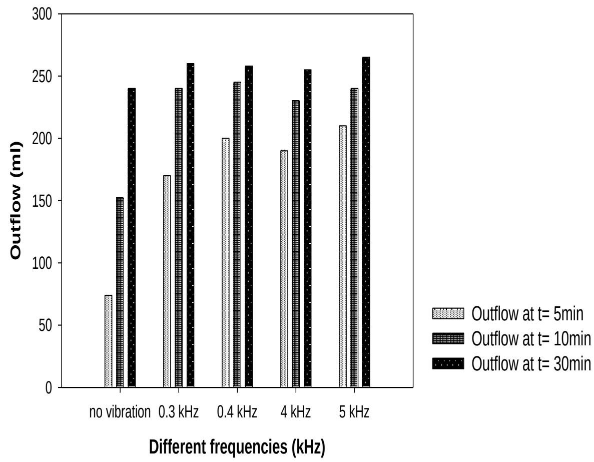

Figure.7 Compare outflow in different time with same amplitude 15v

As shown in Fig. 7, we can see when at t=10min, the difference between using vibration and without vibration is very significant. It indicates that using PVDF film can accelerate the rate of outflow.

2.2.3 Effect of amplitude on dewatering

Fig. 8 shows the effect of amplitude on dewatering at the frequency of 6 kHz

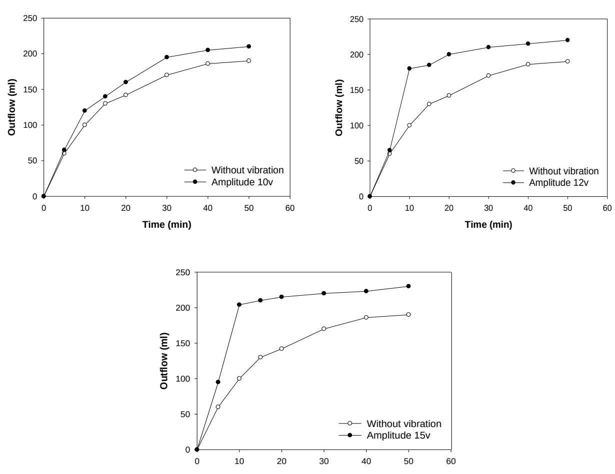

Figure.8 Outflow in different time - frequency 6 kHz

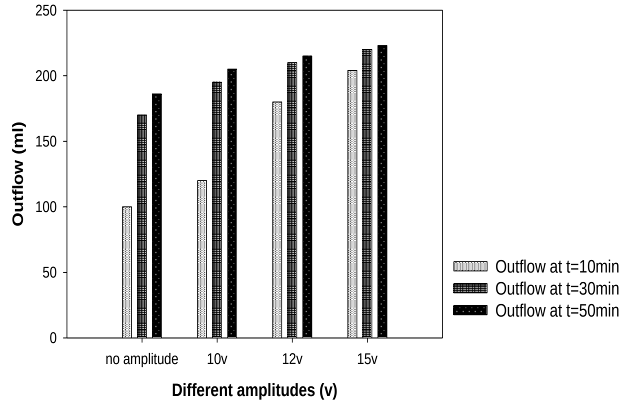

Figure.9 Compare outflow in different time with frequency 6 kHz

As shown in Fig. 8 and Fig.9, we use the value of frequency is 6 kHz which is the best value in the low frequencies and change the amplitudes. Through Fig. 9, we can see that the outflow and pressure have a direct relationship. So when the pressure is 15v which is the largest value in function generator, the outflow is the largest. So if we want to get a desired result. We can give the amplitude the largest value (15v).

Through Fig. 9, we can see at t=10min, the difference between using vibration and not using vibration is very obvious. Using PVDF film can shorten the time which compare with not using vibration. For example, look at Fig. 8, when there are no vibrations, the final outflow is nearly 180ml at *t=50min*. But when using vibration, at *t=10min*, the outflow is already larger than without vibration. So we can say using PVDF film can accelerate the outflow and shorten the dewatering time. When finish a test, the final outflow is larger than not use vibration.

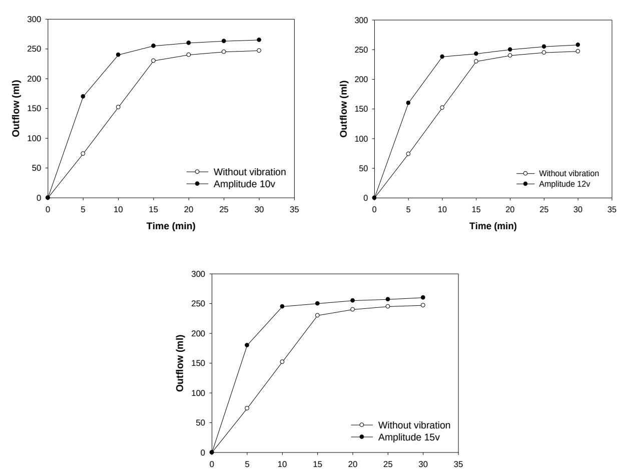

Figure.10 Outflow in different time - frequency 0.3 kHz

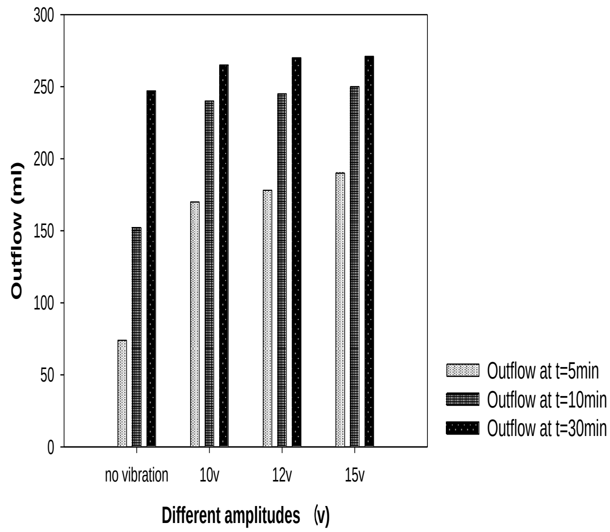

Figure.11 Compare outflow in different time with frequency 0.3 kHz

Fig. 10 and Fig. 11 show the results for the frequency = 0.3 kHz and a various amplitude. We can see the outflow and fluid pressure have a direct relationship. When the pressure is 15v which is the largest value in function generator, the outflow is the largest. When t=10min, the difference between using vibration and not using vibration is very obvious. It indicates using PVDF film can accelerate the rate of outflow. So using PVDF film can shorten the time of dewatering.

2.3 Change the thickness of the soils in the same water content

Table 1 shows some difference water content between using vibration and no using vibration at different time with various soil thicknesses. Through this table, we can see that at the initial stage, the difference water content is very obvious. And with the increasing of thickness of soils, the difference is decreasing. This trend is not obvious at initial time. At initial time, we only can see the rate of outflow is fast. The effect of thickness is not obvious at initial time. When the thickness of soil is increasing, the final difference between using vibration and not using vibration is decreasing and the effect of PVDF film is weaker and weaker.

Table 1. Compare the difference water content between using vibration and without vibration at difference time

Group	Mass (g)	Water (ml)	ω_0[1] (%)	$\Delta\omega_5$[2] %	$\Delta\omega_{10}$[3] %	$\Delta\omega_{30}$[4] %
1	250	200	80	6	4	4
2	350	280	80	3	2	2
3	500	400	80	11	4	2
4	750	600	80	7	5	2

[1] the original water content; [2] denotes the difference between using vibration and not using vibration at t=5min; [3] denotes the difference between using vibration and not using vibration at t=10min; [4] denotes the difference between using vibration and not using vibration at t=30min.

3 CONCLUSION

From the results of this investigation, we concluded that vibrations can significantly increase the flow rate through the saturated soil. Compare the final outflows, we can say using PVDF film has good effect in vibrational dewatering. The volume of outflow with using vibration is larger than that with no-vibration. At initial stage, the rate of outflow is obviously faster than that with no-vibration, so we can say using PVDF film can accelerate the rate of outflow. For the sandy soils, when acoustic pressure is high, the increasing rate of flow rate through porous media is high and optimum frequency in interval 5 kHz to 7 kHz with the frequency=6 kHz, the outflow is better than other case. Outflow and amplitude value have a direct relationship. Using PVDF film obviously shortens the time of dewatering.

The findings obtained in this paper give the determining the influence of mechanical vibrations on fluid flow in porous media. Vibrations were generated using PVDF film with various frequencies as innovative technique. This work may result in new soil remediation and other related technologies.

4 REFERENCES

Young – Uk Kim, Sung – Jae Yang, Jeehyeong Khim and Seungmin Na, “Ultrasonic Effects on Water Flow Through Porous Media”, *International Journal of Offshore and Polar Engineering*, Vol. 16, No. 2, June 2006, pp. 136-152.

Jong-Sub Lee, Jung-Ha Hwang[1], Young Uk Kim[2], and Mian C. Wang[3] , Effect of Ultrasound on Consolidation Behavior of Marine Clay, Jpn. J. Appl. Phys. **47** (2008) pp. 1794-1796.

Young Uk Kim, Junsoo Ha[1], Geonha Kim[2] and Seungmin Na[3] , Ultrasonic Enhancement of Drainage Material Filterability, Jpn. J. Appl. Phys. **45** (2006) pp. 311-313.

Buermann, W., J. Kinzel., December 8-10,1997. *“influence of Mechanical Vibrations on Fluid Flow in Porous Media – Flow by Vibration (in German)”.* Institute for Hydromechanics, University of Karlsruhe, Report No. 736, 1997.

Daniel J. Inman, Inc. 2007. “Engineering Vibration” Person Education.