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WATER PRESSURE MEASUREMENT IN DEEP GROUND WATER

Masakuni HORITA[1*]

[1]Shimizu Corporation　Institute of Technology (3-4-17 Echujima, Koto-ku, Tokyo, 135-8530 , Japan)
*E-mail: masakuni.horita@shimz.co.jp

The measurement systems of ground water pressure in deep are grouped into two ways, one measures water pressure directly at the depth, and the other measures the height of water table in a piezo metric tube. There are several points to discuss in the comparison between the direct measurement and the piezometric measurement.
In order to evaluate measured water pressure in deep ground water, there are mainly two factors affecting the measurement record directry. They are atmospheric pressure and earth tide effect. It is important to subtract these effect from real data to get the basic trend of water pressure in deep. The process to get the trend is shown in this papar with example records and the induced problems in the process are pointed out.

Key Words : *groundwater pressure, monitoring, instrumentation, atmospheric pressure, tide effect*

1. INTRODUCTION

The measurement of groundwater pressure is important to evaluate the flow direction, flow quantity, location of aquifers and effects by construction of some underground works. There are several ways to measure the groundwater pressure in deep aquifers. They are two ways in sealing method, buried and puckered, and two ways in measurement methods, direct measurement at the depth and measurement for piezometric water table.

This paper mainly discuss the difference in the measurement systems.

The measurement data of groundwater pressure including the effects of atmospheric pressure and earth tide. The data also include measurement noise depending upon the range of sensors. Subtracting those effect, the tendency of pressure change will be more clear.

2. INSTRUMENTATION METHODS

There are tree different methods for instrumentation of groundwater pressure sensors in deep aquifers in Fig.1. Firstly, the diffence is whether sonsors are buried or free in a casing. The buried system has alternative layers with sand and clay and the sensors buried in sand layer. The packered systems have multiple packers to seal monitoring zones and retrievable sensors. Main differnses between the buried system and packered systems are the retrievability of sensors and the accuracy of depth of monitoring zones.

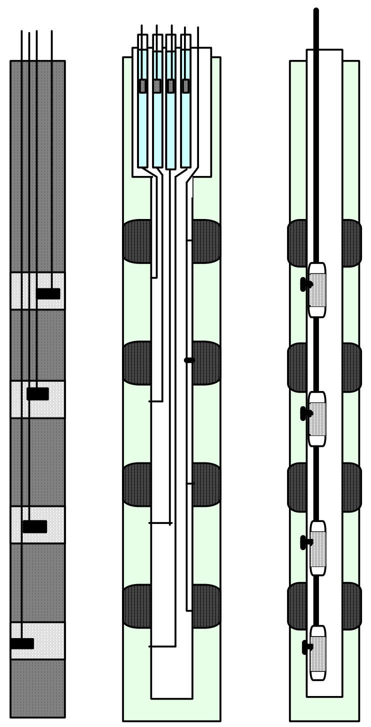

Fig.1 Multiple monitoring systems

3. STAND PIPE SYSTEM VS. REMOVABLE SENSOR SYSTEMS

In the stand pipe system, sensors measure the height of water tables in stand pipes. The pressure at depth is converted from the piezometric height of water as follows:.

$$p = \gamma_w H \tag{1}$$

where p is pressure at depth, γ_w is unit weight of water, and H is the piezo height measured from the monitoring depth to the water table in the stand pipe.

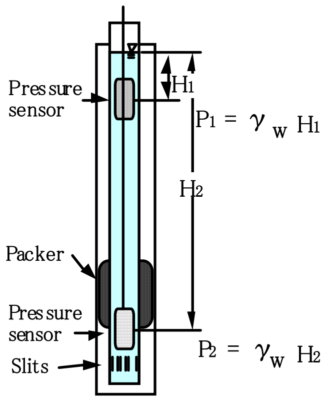

Fig. 2 Evaluation of unit weight of water

The γ_w is evaluated as follows when the pressure is monitored at two different depths as shown in Fig.2.

$$\gamma_w = \frac{P_2 - P_1}{H_2 - H_1} \tag{2}$$

The γ_w changes along the depth and it changes during long term monitoring especially beside a sea shore. The pressure at depth is 3 percents bigger if γ_w=1.03 like saline water comparing with pure water with γ_w=1.0. γ_w is also changed by temperature of water so that the γ_w is changed in depth. The problem will be solved if the sensor is set at the depth of the stand pipe.

There are two types of monitoring probes, one measured pressure directly including atmospheric pressure, and the other mesure differencial pressure from atmospheric pressure. Often the former is used for removable probe systems and the latter is used in stand pipe systems.

It is very difficult because of ununiform of γ_w to compare the data from stand pipe system with those from remobable probe systems.

4. MONITORING ZONES

The measured data at the depth is a point data at the depth, but they are representative for the monitor zone sealed by packes or clay layers in buried case. In a monitor zone, the total pressure head is constant as shown in Fig.3.

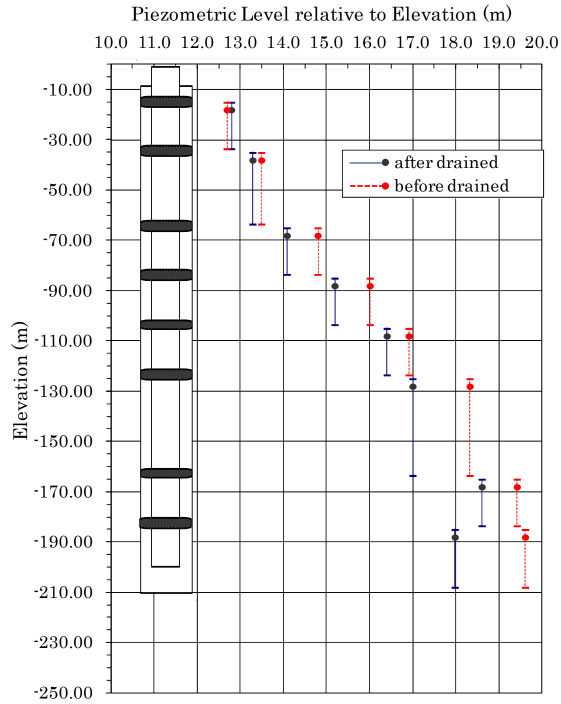

Fig. 3 Pressure distributions in packerd system

The zone pressure is the average pressure if the geology with permeable layer is covered in a zone as shown in Fig.4.

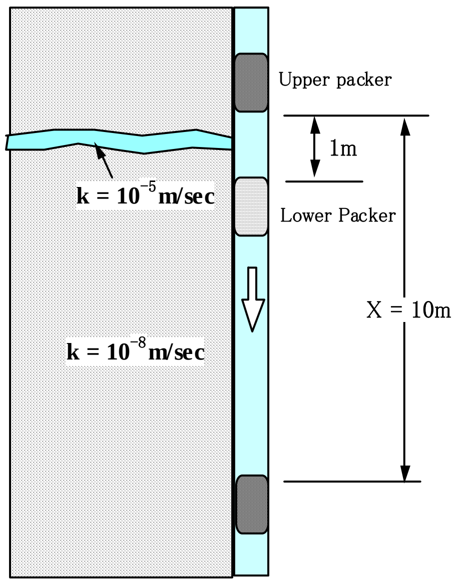

Fig. 4 Monitoring Zone Sealed by two Packers

The zone pressure is very sensitive to a pervious layer, but the response may be evaluated as the response of the sealed zone. For example, compare the 1m packer interval including a pervious layer and the 10m interval cover the same layer as shown in Fig.4. The equivalent permeability of the monitoring zone changes with the packer interbals as shown in Fig.5. The equevalent permeability changes 10 times if the zone length is chaged from 10m to 1m. It is important to cover monitoring site, but in the limitation of numbr of monitoring zones, it is impotant to decide the intervals of sealed monitoring zones.

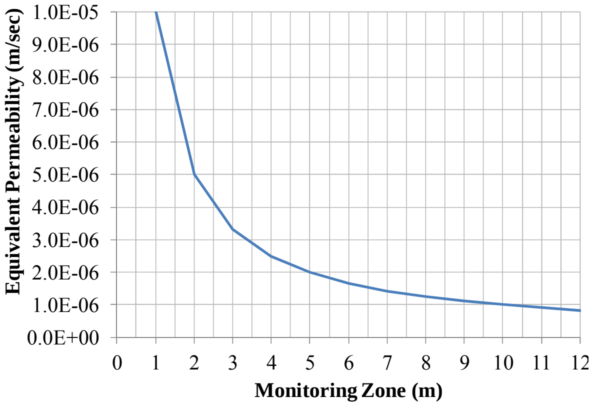

Fig.5 Evaluation of Equivalent Permeability of Monitoring Zone

5. MONITORING DATA FOR DEEP PRESSURE MEASUREMENT

The monitoring record of groundwater pressure like Fig.6 includes the effect of atmospheric pressure, the effect of earth tide, and noise of a sensor.

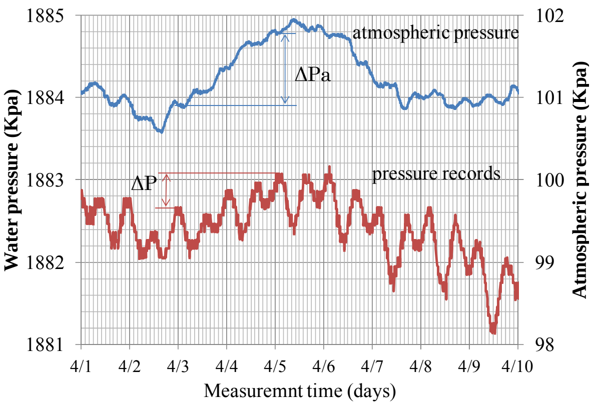

Fig. 6 Pressure records and atmospheric pressure

(1) Atmospheric pressure

The magnitsude of effect of the atmospheric pressure differs due to the depth of measurement and due to the characteristics of zone and/or the geology. The tendency of the atmospheric pressure is fixed at the measurement zone. The subtraction of effect of atmospheric pressure is shown as follows;

$$p' = p - \left\{p_{a0} + \frac{\Delta p}{\Delta p_a}\left(p_a - p_{a0}\right)\right\} \qquad (3)$$

where p' is the ground water pressure, p is the measured pressure including atmospheric pressure, p_{a0} is the reference atmosphere, p_a is the measured atmosphere, Δp is the measured pressure difference and Δp_a is the atmospheric pressure difference shown in Fig.6.

Fig.7 shows the result after subrtracting the effect of atmospheric pressure.

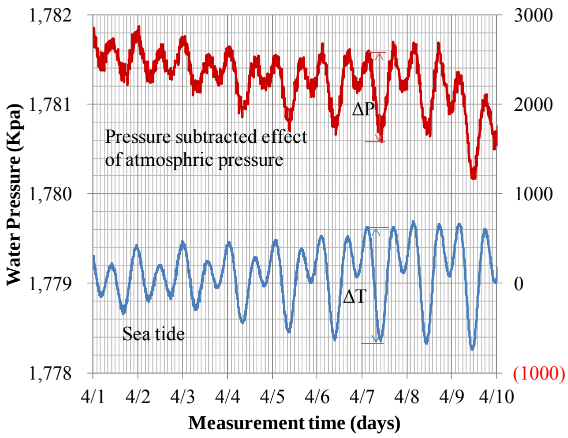

Fig. 7 Pressure subtracted effect of atmospheric pressure and Sea Tide Fractuation

(2) Earth tide

Fig.7 also shows the sea tide fractuation measured at a port near the monitoring site. The earth tide was not measured at the site. The sea tide near the site is used for a reference to the earth tide at the site. The sea tide is provided by the Geographical Survey institsute. It is very clear to see the correspondence between the measured data and tide. The tide effect is easily subtract from the pressure data as follows;

$$p' = p - \frac{\Delta p}{\Delta T}\,T \qquad (4)$$

where p' is the ground water pressure after subtracted the effect of earth tide, p is the measured pressure, Δp is the diffence of pressure during the change of tide ΔT, and T is the measured tide hight. The value of $\Delta p/\Delta T$ is differ in each monitoring depth, and normally larger value in deeper zone.

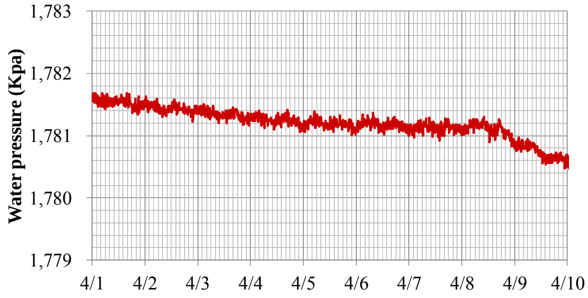

Fig.8 Pressure Trend after subtracted effects of atmospheric pressure and tide

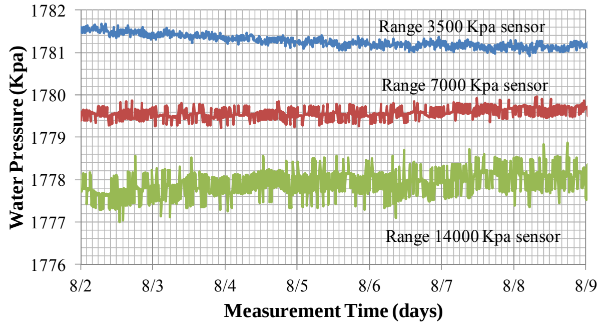

Fig.9 Comparison of noise in different range of sensor

The result of subtraction of tide factor is shown in Fig.8. It is much easy to evaluate the tendency of pressure change comparing with the original data , Fig.6. It shows constant decrease of pressure from April 1 to April 8 and shows a clear bending point in April 8 and the rate of decleasing becomes steeper after the point. Scince $\Delta p/\Delta T$ is constant at each measurement zone, it is comvenient to determin those constants using compatibly calm data set, which do not show large pressure fractuation with clear atmospheric change and tide fractuation.

(3) Recorded Noise

Fig.8 includs the measured noise. Fig.9 shows some examples of measured noise of pressure by sensors with different range. For the comparison purpose in noise amplitude, the lines of 500 Kpa and 1400 Kpa are shifted by arbitrary amount. The magnitudes of measured noise are summarized in Table 1. The magnitude of noise propotionally increases with the measurement range of a sensor. Not only the range of a sensor but also its noise factor must be considered when the sensors are selected for each depth of measurement.

Table 1 Noise of Pressure Sensor

range of sensor		Noise	
Kpa	psi	Kpa	rate
210	30	0.01	0.000048 F.S.
700	100	0.02	0.000029 F.S.
3500	500	0.10	0.000029 F.S.
7000	1000	0.20	0.000029 F.S.
14000	2000	0.36	0.000026 F.S.

6. CONCLUSION

This paper include some discussion in comparing stand pipe system with removable probe system in multi-packered measurement system of ground water pressure.

The difficulty of measurring unit weight of water preventing the direct comparison between two systems.

It is important to design the intervals of packer because total head is equalized in a monitoring zone.

A simple method to evaluate pressure measurent record is shown. In the method, the effects of atmospheric ptessure and earth tide are subtract from original record in step by step. Noize factor must be considered to select the range of sensor maching to monitoring purpose.

深部地下水の水圧計測

堀田　政國

深部地下水の水圧計測システムは大きく二通りに分けられる．一つは所定の深度で直接水圧を測定するもの，もう一方はスタンドパイプ内のピエゾ水面を計測するものである．二つの計測手法を比較し，その検証手法を検討する．

水圧の直接計測値には主に二つの影響を与える要素がある．一つは大気圧変動であり，もう一つは地球潮汐の影響である．地下水変動の経時変化を検討する場合，これらの影響を差し引いた水圧のトレンド成分で評価すると，地下水変動の傾向がわかりやすい．本論文ではこのトレンド成分の簡易算定法を示し，その問題点を抽出する．