COMMISSION INTERNATIONALE
DES GRANDS BARRAGES

CONGRÈS
DES GRANDS BARRAGES
Barcelona, juin 2006

PERFORMANCE OF WIRELESS PORE WATER PRESSURE TRANSDUCER INSTALLED WITHIN EMBANKMENT DAMS (*)

Yuji KOHGO
Head, Lab. of Eng. Analysis, Dr. of Agr.
National Institute for Rural Engineering

Isamu ASANO
Senior Researcher, Lab. of Eng. Analysis, Dr. of Agr.
National Institute for Rural Engineering

Yoichi HAYASHIDA
Researcher, Lab. of Eng. Analysis, Ms. of Agr.
National Institute for Rural Engineering

Akira TAKAHASHI
Deputy Manager, Dam Group,
Construction Eng. Center, Ms. of Eng.
Tokyo Electric Company

Ryoichi TOMEZUKA
Section Chief, Planning Dept., Bs. of Eng.
Sakatadenki Co. Lit.

JAPAN

1. INTRODUCTION

It is very important to measure pore water pressures within embankments and foundations in order to monitor the stabilities of fill dams. In the measurement of pore water pressures, pore water pressure gauges, which were connected with cables to the data loggers located on the ground surfaces, were used. The cables were utilized to transfer measurement data and supply power sources. However, there are following shortcomings in the use of the gauges with cables.

(1) To reduce stabilities of embankments: Cable trenches become weak points

(*) *COMPORTEMENT DE CAPTEURS DE PRESSIONS INTERSTICIELLES SANS FIL EQUIPANT DES BARRAGES EN REMBLAIS*

because of lack of compaction and in some cases water paths may be formed along the trenches,
(2) To trigger breakdown of gauges: Breakage and insulation reduction of cables, and lightning surge trigger breakdown of the gauges,
(3) To be obstacles against construction: It takes long time to install the gauges. Construction operations are interrupted during the installations,
(4) Low cost performance: The more cost takes as the total length of cables becomes longer.

In order to overcome these shortcomings, a type of wireless pore water pressure transducers was developed. In this transducer, a low frequency electromagnetic wave (8.5kHz) and the latest digital transfer technique were used.

The purposes of this paper are to introduce the wireless transducer and to indicate the performance of the transducers installed within embankments of dams. At first, outline and theoretical principle will be described and then some experimental tests conducted in order to verify the design specifications will be briefly mentioned. Finally, the performance of the wireless pore water pressure transducers will be verified by comparing between the data measured from the wireless transducers and those from conventional pressure gauges with cables.

2. OUTLINE OF WIRELESS PORE WATER TRANSDUCER DEVELOPED

2.1. WIRELESS PORE WATER PRESSURE TRANSDUCER

In this design concept, the specifications of the transducers required are as follows. The distance of transmission within soils is more than 100 m, the dimensions of the transducer are smaller than the maximum particle size of impervious core materials, the life is more than 10 years, waterproof is more than 3MPa, and the density of the transducer is almost the same as that of gravels. In order to satisfy the specifications, we utilized 8.5 kHz electromagnetic wave, latest digital transfer technique, power-saved electric circuit, lithic batteries and FRP (Fiber Reinforced Plastics) case. Figure 1 shows an illustration of difference between the wireless transducers and conventional gauges with cables installed in an embankment dam. The wireless system consists of data communicate devices (surface device), which set on an embankment surface and or in an inspection gallery, and transducers installed within an embankment dam.

Figure 2 shows the structure of the wireless transducer developed. The dimensions are 125 mm in diameter and 205 mm in height. The transducer mainly consists of a pore water pressure gauge, printed circuit boards, three size D batteries, and an antenna coil. It has functions of storing, transmitting and receiving of data. Once the transducer received commands from the surface device, it can send data stored to the surface device.

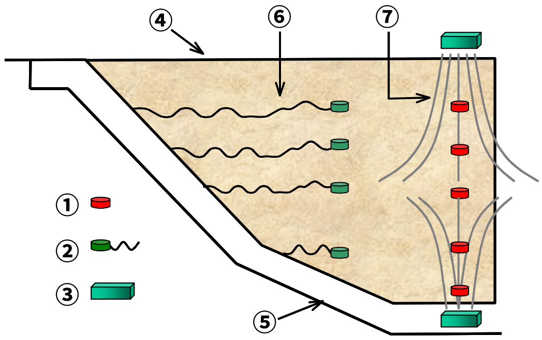

Figure 1
Comparison of wireless pore water pressure transducers with the conventional gauges with cables.

Comparaison entre capteurs de pressions interstitielles sans fils et capteurs classiques câblés

①Wireless pore water pressure transducer
②Conventional pore water pressure gauge with cable
③Surface device
④Embankment
⑤Inspection gallery
⑥Cables
⑦Low frequency electromagnetic wave (8.5kHz)

①Capteur sans fils
②Capteur classique câblé
③Dispositif de communication
④Remblais
⑤Gallerie de visite
⑥Câbles
⑦Onde électromagnétique basse fréquence (8.5 kHz)

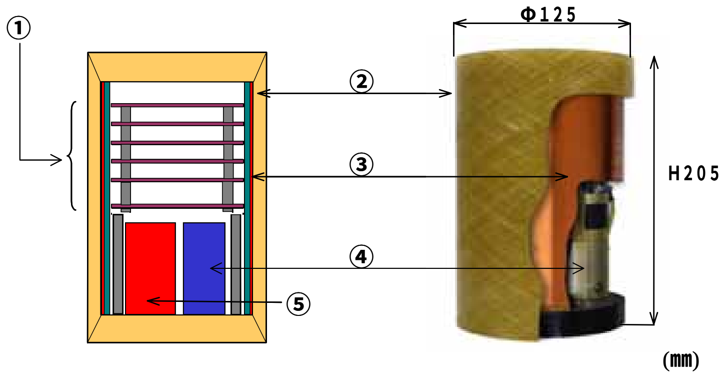

Figure 2
Structure of wireless pore water pressure transducer.

Structure du capteur de pressions interstitielles sans fils

①Printed circuit board
②Case (FRP)
③Communication antenna
④Pore water pressure gauge
⑤Size D Batteries (3 packs)

①Carte de circuit imprimé
②Boitier (PRF)
③Antenne de transmission
④Cellule de pression
⑤Batteries (format D, 3 jeux)

Figure 3 shows a schematic figure for the underground communication system developed here. The communications between wireless transducers and the surface device are conducted with 8.5kHz electromagnetic wave. The digital signals (0 or 1 figures) are identified using phase shift keying (PSK) technique. The S/N ratio (signal-to-noise ratio) needs to be more than 2. In reality, the most efficient communications can be conducted when the antenna in the wireless transducer is set parallel to that in the surface device as shown in this figure. The vertical axes of both antennas are namely parallel each other. It is found from some experimental data that in this case, the receiving voltage is almost equal to the theoretical value (kH_y: referring next section). In order to obtain the sufficient communications, we investigated the setting procedure of wireless transducers where the inclines of the transducers become as small as possible when setting them. This will be described in section 4.1.

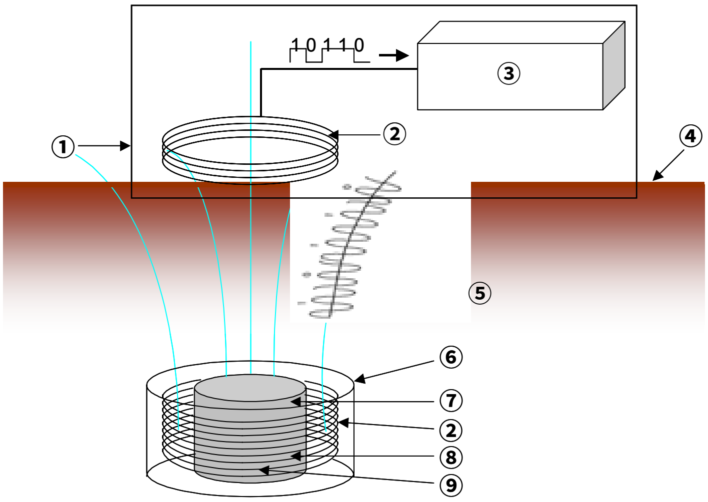

Figure 3
Schematic view of underground wireless communication system

Croquis du système de communication enterré

①Surface device	*①Dispositif de surface*
②Antenna	*②Antenne*
③Communication controller	*③Controlleur*
④Surface of ground	*④Surface du terrain*
⑤Communication signal	*⑤Signal émis*
⑥Case	*⑥Boitier*
⑦Transmitter, Data logger	*⑦Emetteur, enregistreur de données*
⑧Battery	*⑧Batterie*
⑨Pore water pressure transducer	*⑨Capteur de pressions interstiticielles*

2.2. TRANSMISSION PRINCIPALS WITHIN SOILS

The wireless transducer can communicate to the surface device with a low frequency electromagnetic wave. In order to explain the transmission principles, let us now consider a small loop antenna for transmission, which has area S and current I, as shown in Figure 4. The intensities of magnetic field H_θ (for θ direction) and H_r (for r direction) at a point with distance r and angle θ from the center of the small antenna are obtained as follows [1].

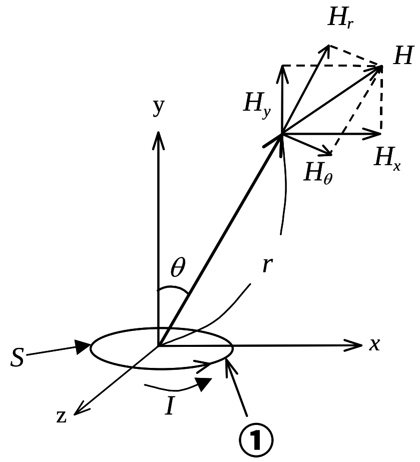

Figure 4
A small antenna.

Petite antenne

①A small loop antenna *①Petite antenne cadre*

$$H_\theta = \frac{j}{2\lambda}\frac{1}{\eta_0}\left(1 + \frac{1}{jkr} + \frac{1}{(jkr)^2}\right)\frac{\exp(-jkr)}{r} j\omega\mu IS\sin\theta\,, \tag{1}$$

$$H_r = \frac{1}{\lambda}\frac{1}{\eta_0}\left(\frac{1}{jkr} + \frac{1}{(jkr)^2}\right)\frac{\exp(-jkr)}{r} j\omega\mu IS\cos\theta\,, \tag{2}$$

$$k = \omega\sqrt{\varepsilon\mu} = \frac{2\pi}{\lambda}\,, \tag{3}$$

$$\eta_0 = \sqrt{\frac{\mu}{\varepsilon}}\,. \tag{4}$$

Where j is imaginary unit, λ wavelength, ε dielectric constant, μ permeability, and ω angular velocity. As described in the previous section, the receiving voltage is almost equal to kH_y, so we address to the value of H_y. The intensity of magnetic field for y direction H_y is given referring Figure 4,

$$H_y = H_r\cos\theta - H_\theta\sin\theta\,. \tag{5}$$

As value of θ is usually small, the value of H_y depends mainly on the value of H_r. If a high frequency of wave is used, value of kr could be remarkably larger than 1. Then the terms of $1/jkr$ and $1/(jkr)^2$ in Equations (1) and (2) may vanish, and the value of H_r is almost equal to 0. Communication with high frequency wave cannot be established. Meanwhile supposing a frequency of wave used is very low, value of kr could be sufficiently smaller than 1. Then the terms of $1/(jkr)^2$ in Equations (1) and (2) may only remain. The value of H_r is inverse proportion to r^3 and the absolute value is given as,

$$\left|H_r\right| = \frac{IS\cos\theta}{2\pi r^3}\ . \qquad (6)$$

It is obviously found from Equation (6) that the absolute value of H_r is independent of properties of propagation media. Thus, if you use a low frequency electromagnetic wave, the attenuation due to distance is remarkably high, but the affection of the properties of propagation media to the attenuation is small.

3. VARIOUS TESTS FOR VERIFICATIONS OF DESIGN SPECIFICATIONS [2]

Five kinds of tests were carried out to investigate the specifications shown in Table 1. They are tests for transmission change due to temperature, mechanical tests for FRP case, waterproof tests, life tests for battery and tests for property of transmission.

3.1. TRANSMISSION CHANGE DUE TO TEMPERATURE

We investigated the lags of the internal timer installed within the transducer due to environmental temperature changes from 0 to 40℃. It was found that the lag in a day was about 2 seconds and this value was within an adjustable range. Transmission tests were carried out within –10 to 50℃. It was found from the test that the transmission was normal.

Table 1

Design specifications for wireless pore water pressure transducer.

Hypothèses de conception d'un capteur de pressions intersticielles sans fils

Carrier frequency	8.5kHz
Communication distance	100m (Underground)
Size	Less than ϕ125mm× H205mm
Measurement frequency	1/day (Automatic mesurement)
Communication frequency	1/week +1/month (Periodical)
Battery life	Over 10 years

3.2. MECHANICAL TESTS FOR FRP CASE

When the transducers are installed within a more than 100m embankment dams, more than 2Mpa earth pressures may be applied to them. It is necessary for the FRP case of the transducer to bear such earth pressures. We have also to consider whether the FRP case is safety or not in such a special situation as that it touches gravels. In such a case stress concentration occurs. So we conducted some experimental compression tests shown in Figure 5. Figure 5 shows three loading patterns that really occur. Pattern 1 is vertical point loading where vertical point loads are applied at the center of the cap and large deformations occur around the connecting part between the cylinder part and the cap of the FRP case. We investigate from the tests whether a leakage through the connecting part occur. Pattern 2 is a line loading that can be normally seen. Pattern 3 is a special case such as that the FRP case touches gravels. Strains were only measured during the tests with strain gauges stuck on the surfaces of the FRP case. A scene of tests is shown in Figure 6.

It was found from Pattern 1 tests that (1) the maximum strain appeared around the connecting part, (2) the strain increased about 1,000μ each 10kN, (3) the strain expressed about 4,000 μ at the maximum load applied, (4) the maximum load was about 40kN, (5) the load-strain relationships were linear elastic, and (6) exceeding 35kN, strains concentrated at the loading point.

Pattern 2 tests showed the following results: (1) the maximum strain was recorded in the gauge stuck vertically at the center of the cylinder, (2) the strain expressed about 2,000 μ at the maximum load applied, and the maximum load was about 50kN, (3) the load-strain relationships were linear elastic, and (4) any collapse cannot be seen.

It was found from Pattern 3 tests that (1) the maximum load was about 40kN, and (2) exceeding 35kN, strains concentrated at the loading point.

From these test results, it was found that each maximum strain obtained in each test was rather smaller than the limit strain of FRP (12,000 μ).

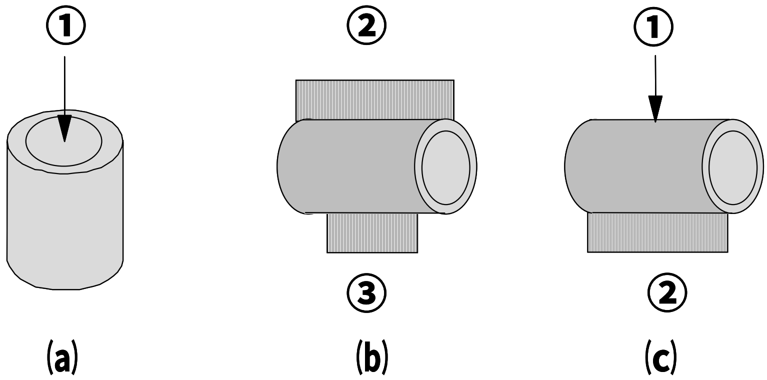

Figure 5

Test Conditions (Loading patterns).

Conditions de l'essai (application de l'effort)

(a) Vertical point loading
(b) Horizontal line loading
(c) Horizontal point loading
①Point loading
②Line loading
③Partially line loading

(a)Chargement ponctuel vertical
(b) Chargement linéaire horizontal
(c) Chargement ponctuel horizontal
①Chargement ponctuel
②Chargement linéaire

③Chargement linéaire partiel

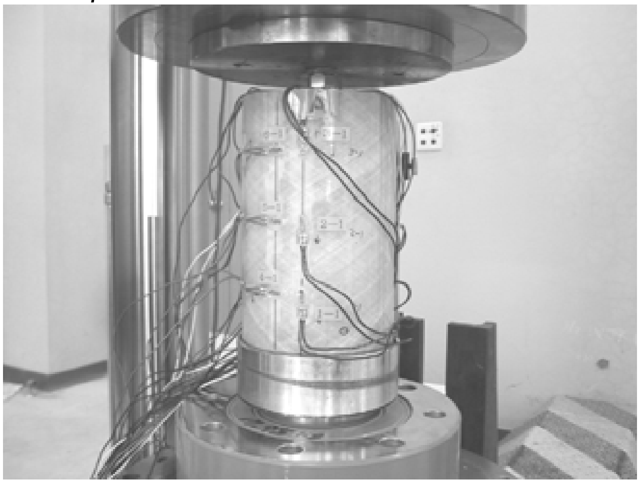

Figure 6
A scene of point loading test.
Vue du dispositif de chargement ponctuel

3.3. WATERPROOF TEST

The transducer was set in a pressure chamber filled with water and was subjected up to 3MPa water pressure in order to check if water came into the transducer. The water pressures were gradually applied and 1, 1.5 and 3MPa pressures kept for 12, 43 and 7 hours, respectively. It was found from the tests that water did not come into the transducer and the FRP case was compressed by about 1700μ strain when 3Mpa pressure applied. The amount of the strain occurred was 14% of the limit strain for FRP. Then, the transducer has a sufficient waterproof.

3.4 LIFE TESTS FOR BATTERIES

The required life of the transducer is more than 10 years. Then, batteries, which can steady supply powers for more than 10 years, are necessary. We used lithic batteries. In order to investigate if the batteries can steady supply powers for more than 10 years, we conducted haste electric discharge tests. These tests were carried out so that regulated discharges were applied to the batteries and the amount of discharges for terms (1/12, 1/2, 2.5 and 10 years adopted) was almost equal to the amount of power consumption of the transducer for 10 years. The batteries used have the capacity 13.0Ah, the self-power consumption less than 2% of the capacity, and the maximum discharge current 2,000mA. The amount of power consumption of the transducer for 10 years was 10.18Ah that was calculated under the condition that pore water pressures were measured once a day.

Figure 7 shows the result of 1/2 (6 months) year discharge test. The voltage of the battery kept more than 3V and was steady after 6 months. Then, batteries used satisfy the specification.

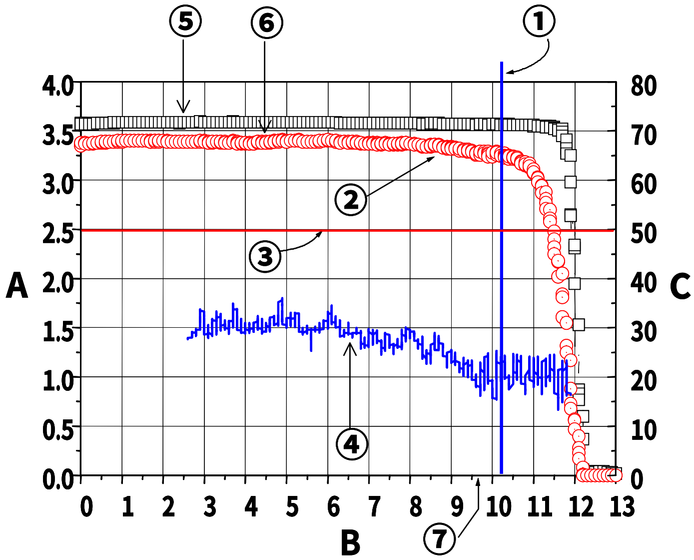

Figure 7
Relationship between voltages and battery capacities for 6 months discharge test.

Batteries: Relation tension / capacité (durée de l'essai: 6 mois)

(A) Voltage (V)
(B) Battery capacity (Ah)
(C) Temperature (℃)
①Elapsed time=6 months: amount of battery capacity is equivalent to the amount that the wireless transducer consumed for 10 years(10,18Ah).
②It does not fall rapidly until battery voltage reaches rated capacity. It means that the battery is long-life.
③The voltage correspond to battery life
④Temperature
⑤Voltage of battery
⑥Voltage (200mA current)
⑦Rating capacity of battery (9.6Ah)

(A) Tension (V)
(B) Capacité (Ah)
(C) Température
①Durée de l'essai = 6 mois. La capacité de la batterie est équivalente à la consommation du dispositif après 10 ans (10.18 Ah).
②La chute se produit lorsque la tension coincide avec la caacité théorique, confirmation de la longue view de la batterie
③La tension correspond à la durée de vie de la batterie
④Température
⑤Tension de la batterie
⑥Tension (intensité 200 mA)
⑦Capacité théorique de la batterie (9,6 Ah)

3.5 PROPERTY OF TRANSMISSION

In order to obtain a fundamental propagation characteristic, communication tests, where media, direction of antennas and transmission power were constant and transmission distances were changed, and measuring noises at the receiving points were conducted. Figure 8 shows an example of the communication tests in the air. Two transmission powers (5.4W and 1.25W) were used. The solid lines are theoretical and symbols are measured values. The theoretical lines were in inverse proportion to r^3 (r: transmission distance) and both experimental and theoretical values were almost consistent. As the mean noise level was 0.21mVrms in these cases, the S/N ratio at the point with 100m distance for 5.4W case was 2.8 that was larger than 2. Then, we could obtain that the communication distance was more than 100m.

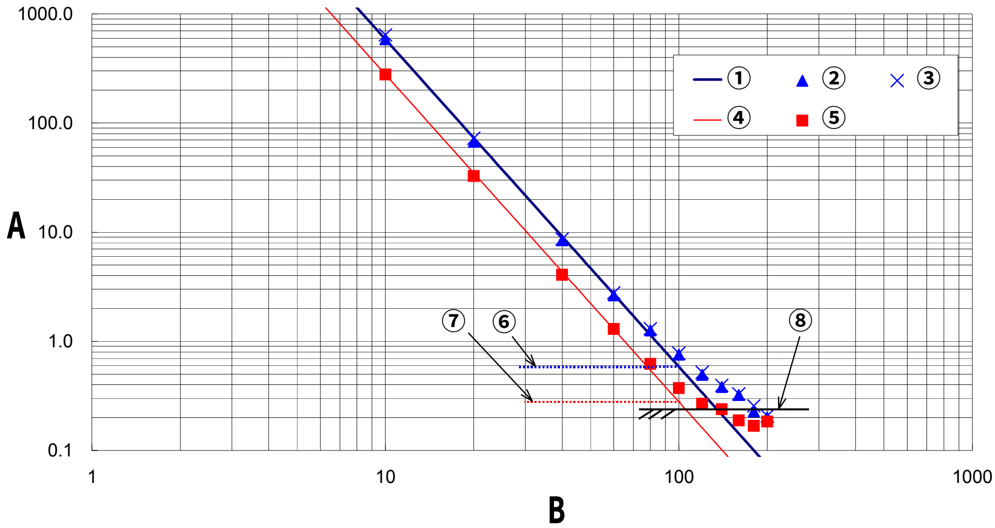

Figure 8
Relationship between received signal voltages and transmission distances in the air.

Relation entre la tension du signal à la réception et la distance de transmission dans l'air

(A) Received signal voltage (mVrms)
(B) Transmission distance (m)
①Theoretical propagation characteristics in the air (5.4W)
②Measured value (5.4W outward)
③Measured value (5.4W return)
④Theoretical propagation characteristics in the air (1.25W)
⑤Measured value (1.25W)
⑥Transmission power 5.4W 0.59mVrms/100m
⑦Transmission power 1.25W 0.28mVrms/100m
⑧Average background noise voltage 0.21 mVrms

(A) Tension du signal à la rectpion (mVeff)
(B) Distance de transmission (m)
①Caractéristiques théoriques de propagatin dans l'air (5,4 W)
②Véleur mesurée (5,4 W aller)
③Valeur mesurée (5,4 W retour)
④Caractéristiques théoriques de propagation dans l'air (1,25 W)
⑤Valeur mesurée (1,25 W)
⑥Puissance de transmission 5,4 W 0,59 mWeff/100m
⑦Puissance de transmission 1,25 W 0,28 mVeff/100m
⑧Bruit de fond (tension) 0,21 mVeff

In a real embankment dam under construction, the similar transmission test was conducted. In the test, a wireless transducer was set within an inspection gallery and the surface device lay on the dam surface. Then, as the embankment level went up, transmission length increased. It was found from the test that the transmission distance was also in inverse proportion to r^3. Then, the transmission characteristic in soils was almost the same as that in the air.

Figure 9 shows noises measured in a dam site. The noise levels were very different at each point. It is very important to survey noise levels around receiving points, for the communication distances depend on propagation characteristics and noise levels at receiving points.

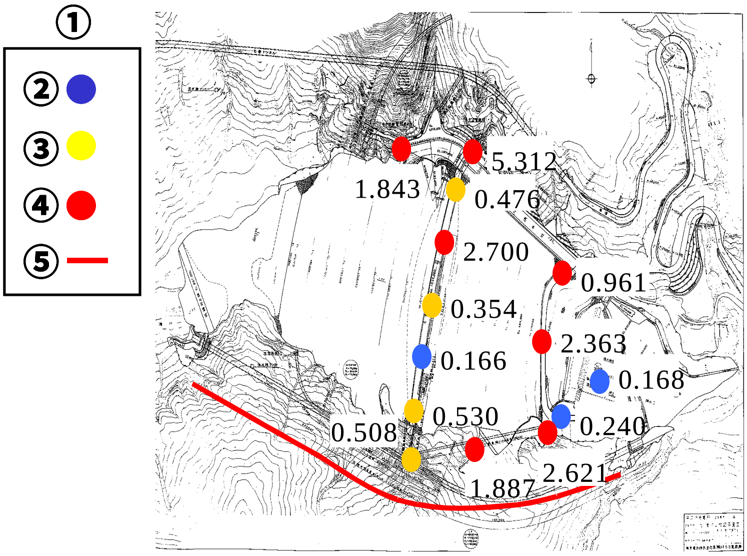

Figure 9
An example of noise levels in an existing dam site.

Exemple de bruit de fond au site d'un barrage existant

①Noise level
②0-0.2 mVrms
③0.24-0.70 mVrms
④Over 0.70 mVrms
⑤Electric wire

①Bruit de fond
②0-0,2 mVeff
③0,24 – 0,70 mVeff
④> 0,70 mVeff
⑤Fil électrique

4. PERFORMANCE OF WIRELESS TRANSDUCERS INSTALLED IN REAL EMBANKMENTS

4.1 SETTING PROCEDURE OF WIRELESS TRANSDUCER [3]

In order to obtain the sufficient communications, we investigated the setting procedure of wireless transducers where the inclines of the transducers become as small as possible when setting them. Here we conducted insitu install tests of the transducers. Two procedures (Conventional method and Core boring method) were adopted. In the Conventional method, a transducer lies on a setting level and is installed by compacting thin layers surround it as shown in Figure 10(A), while in the Core boring method, a compacted layer is cored out, the transducer is put into the hole and the space between walls of the hole and the transducer is filled with the fill material passed through 2mm sieve as shown in Figure 10(B). In these tests, two transducers were installed within an embankment (Height=90cm, Crest width=8m and Crest length=15m with 1:1 slopes). The height of points installed was 30cm. During the tests, inclines of transducers were measured.

Figure 11 shows the incline changes at every work stages. The inclines with Core boring method were smaller than those with Conventional method. When we install the transducers within real embankment dams, we will employ the Core boring method.

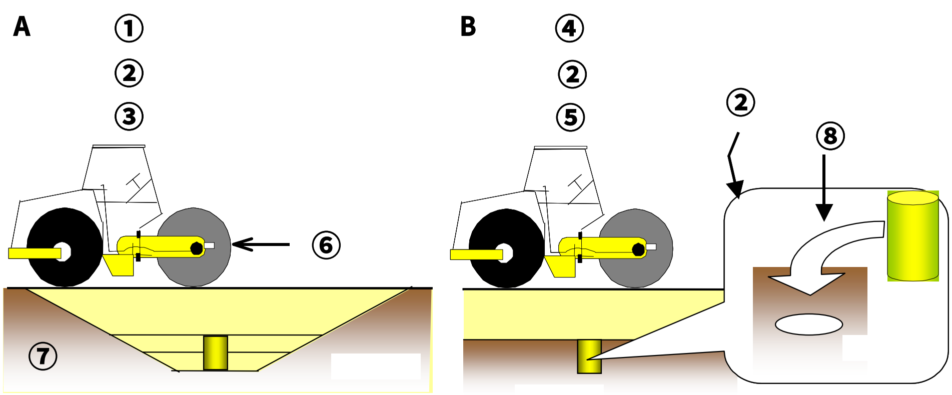

Figure 10
Setting procedures of wireless pore water pressure transducer.

Procédure de mise en place d'un capteur de pression interstitielle sans fil

(A) Conventional method
(B) Core boring method
①Excavating trench
②Setting a transducer
③Compacting core with thin layers
④Boring a core
⑤Compacting core
⑥Vibrating roller
⑦Construction layer
⑧Core boring

(A)Méthode classique
(B) Forage carotté
①Excavation d'une tranchée

②Mise en place d'un capteur
③Compctage du noyau en couches minces
④Exécution d'un forage carroté
⑤Compactage du noyau
⑥Compactage au rouleau vibrant
⑦Couche de remblai
⑧Forage carroté

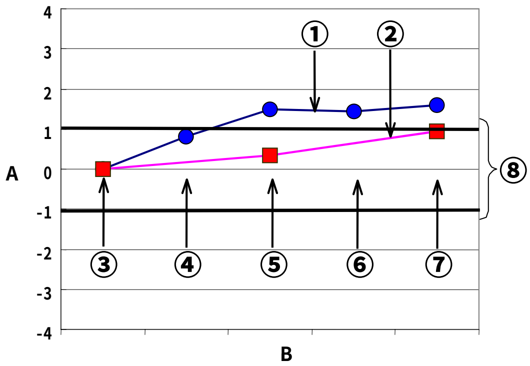

Figure 11
The degree of angle of transducer inclines to vertical at every work stages

Ecart de verticalité d'un capteur lors des différents phase des travaux

(A) The degree of angle of inclination to Vertical (degree)
(B) Work stages
①Conventional method
②Core boring method
③Setting transducers
④Spreading first layer
⑤Compacting first layer
⑥Spreading second layer
⑦Compacting second layer
⑧Target range

(A)Ecart de verticalité (°)
(B)Phase des travaux
①Méthode classique
②Forage carroté
③Pose des capteurs
④Répandage de la première couche de remblais
⑤Compactage de la première couche de remblais
⑥Répandage de la dexième couche
⑦Compactage de la deuxième couche de remblais
⑧Ecart souhaité

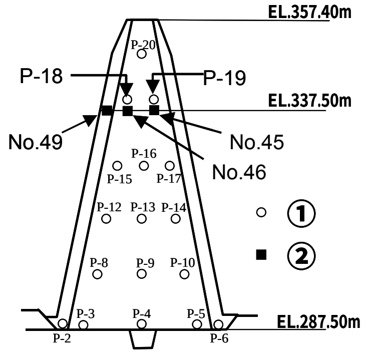

Figure 12

Setting points of wireless pore water pressure transducers on a cross section (N Dam).

Distribution dans le profil de mesure des capteurs de pression interstitielles sans fil (Barrage N)

①Conventional pore water pressure gauges
②Wireless pore water pressure transducer

①Capteurs de pression classiques
②Capteur de pression sans fil

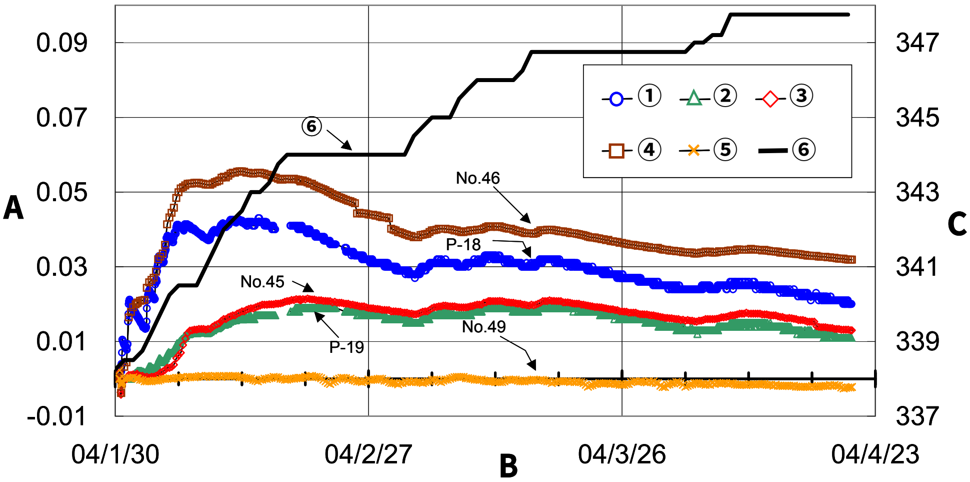

Figure 13
Comparison between pore water pressures measured with wireless transducers and with conventional gages with cables (N Dam).

Comparaison des valeurs mesurées par les capteurs sans fil et par les capteurs classiques câblés (Barrage N)

(A) Pore water pressure (MPa)
(B) Time (main scale: 28 days, sub scale: 7 days)
(C) Embankment surface elevation (m)
①P-18(Conventional)
②P-19(Conventional)
③No.45 (Wireless, downstream of the core, near P19)
④No.46(Wireless, upstream of the core, near P18)
⑤No.49(Wireless, upstream of the filter zone)
⑥Embankment surface elevation

(A)Pression interstitcelle (MPa)
(B)Temps (échelle principale: 28 jours, échelle secondaire: 7 jours)
(C)Cote du remblai (m)
①P-18 (classique)
②P-19 (classique)
③N° 45 (sans fil, coté aval du noyau, près de P19)
④N° 46 (sans fil, coté amont du noyau, près de P18)
⑤N° 49 (sans fil, coté amont du filtre
⑥Cote du remblai

4.2 INSTALLATION OF TRANSDUCERS WITHIN REAL EMBANKMENT DAMS

The wireless transducers developed here were installed within two real embankment dams (N and K dams) in order to investigate their real behavior. Figure 12 shows the setting points of the wireless transducers on the maximum close section of N dam (H=69.9m, total storage volume=4.31Mm^3) [4]. The No. 49 transducer was installed within the filter zone and other two (Nos. 45 and 46 transducers) were in the impervious core zone. The conventional pore water pressure gauges Nos. P-18 and P-19 were installed associated with Nos. 46 and 45 wireless transducers, respectively. The setting level was EL. 337.5m below about 20m of the crest.

Figure 13 shows comparison between pore water pressure values measured with wireless transducers and conventional gauges with cables. It was found from this figure that (1) pore water pressures increased as the surface elevation went up and the pressures decreased when the elevation was constant, (2) there was little bit difference between values of No.46 and P-18 but the profiles were almost the same, (3) the values of No.45 and P-19 were well consistent each other, and (4) the values of No. 49 showed minus values. As the wireless transducer was installed within the filter zone, the values were reasonable.

Figure 14 shows the setting points of the wireless transducers on the maximum close section of K dam (H=50m, total storage volume=2.00Mm^3). The WP1 and WP5 transducers were installed within the upstream and downstream rock zones, respectively and other three (WP2, WP3 and WP4 transducers) were in the impervious core zone. The setting level was EL. 215.0m below 29m of the crest.

Figure 15 shows pore water pressure values measured with wireless transducers. It was found from this figure that (1) pore water pressures of WP2, WP3 and WP4 expressed high values and those of WP1 and WP5 remained low and almost constant values, (2) the pore water pressures measured in the impervious core repeated to increase and decrease as the surface elevation went up and was constant. Such behavior of pore water pressures seemed to be reasonable comparing data already measured in a lot of embankment dams.

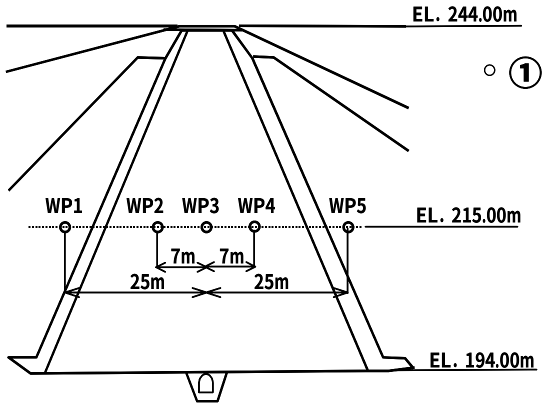

Figure 14
Setting points of wireless pore water pressure transducers on a cross section.
(K Dam).
Distribution dans le profil de mesure des capteurs de pression intersticielles sans

fil (Barrage K)

①Wireless pore water pressure transducer

①Capteur de pression interstitielle sans fil

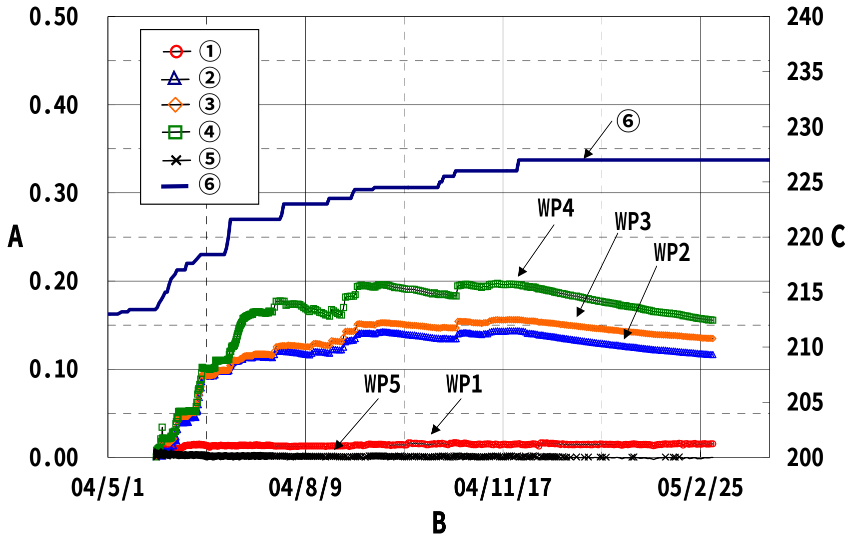

Figure 15
Pore water pressures measured with wireless transducers (K Dam)

Valeurs des pressions interstitielles mesurées par les capteurs sans fil (Barrage K)

(A) Pore water pressure (MPa)
(B) Time (main scale: 100 days, sub scale: 50 days)
(C) Embankment surface elevation (m)
①WP-1(Upstream of rock zone)
②WP-2(Upstream of core)
③WP-3(Center of core)
④WP-4(Downstream of core)
⑤WP-5(Downstream of rock zone)
⑥Embankment surface elevation

(A)Pression interstitielle (MPa)
(B)Temps (echelle principale: 100 jours, echelle secondaire: 50 jours
(C)Cote du remblai (m)
①WP-1 (coté amont du remblais en enrochements)
②WP-2 (coté amont du noyau)
③WP-3 (au milieu du noyau)
④WP-4 (coté aval du noyau)
⑤WP-5 (coté aval des enrochements)
⑥Cote du remblai

5. CONCLUSION

We developed wireless pore water pressure transducers that can communicate to a surface devise by using a low frequency electromagnetic wave. We investigated through various experimental tests if the transducer satisfied their design specifications. It was confirmed from these tests that the transducers could express more than 100 m underground-communication, the lives were more than 10 years, and the waterproof was more than 3MPa. The pore water pressure values measured by these wireless transducers were compared with those of conventional pressure gauges with cables. It was found from the results that both values measured were well consistent.

ACKNOWLEDGEMENTS

We would like to express our gratitude to Mr. Kakuei, Mr. Yano, Mr. Sakata and Mr. Endoh for their valuable suggestions and supports. We would also like to thank many staffs of Ministry of Agricultural, Forestry and Fisheries for their financial and manpower supports.

REFERENCES

[1] Matsumoto, K. (1978). Introduction to electromagnetic wave engineering, Asakura-shoten, (in Japanese).
[2] Kohgo, Y., Asano, I. and Hayashida, Y. (2003). Development of wireless pore water pressure transducers and their application to fill-dams, *SDERD* Vol. 57, 7-18 (in Japanese).
[3] Takahashi, A., Kohgo, Y., Endoh, S., Kakuei, T. and Ohtsuki, T. (2003). Application of wireless pore water pressure transducers to a fill-dam, *Proc. 38th Congress on Geotechnical Engineering,* JGS, 1271-1272 (in Japanese).
[4] Kohgo, Y., Asano, I., Hayashida, Y., Takahashi, A. and Towmezuka, R. (2004). On wireless pore water pressure transducer for fill-type dam, New Developments in Dam Eng., Proc. 4th Int. Conf. on Dam Eng., Nanjing, China, A. A. Balkema, 441-450.

SUMMARY

The purposes of this paper are to introduce a type of wireless transducer and to indicate the performance of the transducers installed within embankments of dams. Some experimental tests were conducted to investigate the design specifications. It was confirmed from these tests that the transducers could express more than 100 m underground-communication, the lives were more than 10 years, and the waterproof was more than 3MPa etc. The installation procedure was also investigated. The pore water pressure values measured by these wireless transducers were compared with those of conventional pressure gauges with cables. It was found from the results that both values measured were consistent.

RÉSUMÉ

Ce document présente un nouveau type de capteurs sans fils, avec indication du comportement noyés dans les remblais d'un certain nombre de barrages. Des expérimentations conduites pour tester les critères de conception des ces capteurs ont confirmé les avantages prévus, notamment: communication à partir d'une profondeur de plus de 100m; durée de vie supérieure à 10 ans; étanchéité sous une pression hydrostatique de plus de 3 MPa. La procédure de mise en place fut également testée. La comparaison entre les pressions interstcielles mesurées à l'aide de ces capteurs et de celles mesurées par les capteurs classiques a montré la cohérence des deux séries de valeurs.