Combined Tomographic Survey of Dams, Evaluation of Strength and Remedial Measures - A Study on Kuttiyadi Irrigation Project

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***Abstract*-- Maximum number of big dams are actually old and regular monitoring and maintenance of these dams is of utmost importance for continuing benefits to society. Distructive testing are not suitable for investigation of leaks in dams Present experimental Study consist of various geophysical techniques with emphasis on their integration to provide unique solutions to subsurface challenges in dam. This study was also aimed to suggest some remedial measures in reducing leakage problems on the basis of study conducted at Kuttiyadi Irrigation Project. Geophysical surveys used in study are Electrical resistivity tomography (ERT), Self-Potential (SP) Seismic refraction Tomography and Ground Penetrating Radar (GPR),. Also studied application of xypex as a remedial measure.**

Keywords: Geophysical surveys, Electrical resistivity tomography (ERT), Self-Potential (SP), Ground Penetrating Radar (GPR), Seismic refraction Tomography, seepage, leakage, earth dam.

I. INTRODUCTION

In ancient times, dams were constructed for the particular purpose of water supply or irrigation. Now Dams in the country denote a major investment and huge benefits to population in terms of irrigation, power and flood control. Big dams are very old and regular monitoring and maintenance of these dams is of utmost importance for continuing benefits. Distructive testing are not suitable for investigation of leaks in dams

It is acknowledged that dams need periodic inspection and monitoring, recently recognized that geophysical surveys can supplement the results of standard inspection and monitoring techniques. These type of study have been completed on a number of dams around the world, and have generated really useful insight into dam conditions.

Presently the peruvanamuzhi dam Kuttiyadi Irrigation Project) is selected for DRIP (Dam Rehabiltation and Improvement Programme) by central government. Present experimental Study consist of various geophysical techniques with emphasis on their integration to provide unique solutions to subsurface challenges in peruvanamuzhi dam. This study was also aimed to suggest some remedial measures to reduce leakage problems.

Seismic refraction surveys are used to get a cross-section of the dam embankment and foundation materials in terms of seismic characteristics. Self-Potential (SP) surveys are used to investigate seepage conditions within dam embankment and foundation materials, and abutment materials. Electrical Resistivity Tomography is also used on dams to determine internal saturation conditions in dams. ReMi is effectively used to determine shear wave velocities (V_s) in dams

II. GEOPHYSICAL METHODS

A. Ground penetrating radar

GPR is a non-destructive and non-invasive technique used to procure a cross sectional view of objects embedded within the subsurface. However it is also known to be used for detection, characterization and evaluation of potential losses of water through a dam (Acerenza Dam in Italy), air pockets or voids and cracks inside a structure, etc. GPR uses an electromagnetic pulse to determine the reflective values of objects in the concrete. It is a send and receive technology like any other geophysical method. The radar sends an electromagnetic pulse (in the microwave band VHF/UHF) from the surface and reflections are received at the surface. It requires access from one side only and is non invasive. This instrument basically consists of three components a power supply, control unit and antenna (transmitting and receiving Antennas). Small recharge batteries to vehicle batteries can be used for generating power supply. During a scan the control unit produces and regulates a pulse of radar energy, which is amplified and transmitted into the sub surface by the transmitting antenna at a specific frequency. The antenna frequency is inversely proportional to penetration depth. And if the frequency is reduced the resolution is affected. The receiving antenna receives the reflected energy and the control unit records the strength and time required for the return of energy.

B. Streaming Potential

Streaming potentials are one of the four possible electro kinetic phenomena that relate electric currents with the relative movement of solid and liquid phases in contact with each other, the other three being diffusion potential, mineralization potential and Shale potential. The streaming

potential phenomenon describes the occurrence of electric potential differences when a liquid moves with respect to a solid that it is in contact with. These potentials are called self potentials due to the absence of any artificially injected electric current. Streaming potentials are very interesting in that they provide information directly related to subsurface flows. Other geophysical methods provide only secondary information about the effects of subsurface flows; however this secondary information helps in interpreting the results from SP measurements.

Flow of gases and liquids through pipes, leakage of a reservoir within the foundation and or abutment of dam, movement of ionic fluids into and through ground water, flow of geo thermal fluids etc can be the origin of streaming potentials. In geophysical terms, electric potential differences are developed in the ground wherever groundwater movements occur in deposits of soil or porous rock.

A basic unit for conducting SP survey consists of a base electrode, a roving electrode, wire and a precise miilivoltmeter. Any voltmeter used in SP investigation should have a relatively high input impedance, at least I08 ohms, in order to prevent drawing appreciable current from the ground, which would disturb the potential distribution and cause polarisation of the electrodes. The resolution of the voltmeter should be .1 or 1 mV. The electrodes in contact with the ground should be the non polarizing type called porous pots which are nothing but metal electrodes suspended in a super saturated solution of their own salts. The wire should be should be strong, hardy and of low resistance, preferably twisted, 18 gauge multi strand copper wire.

3.Electrical Resistivity Tomography

Electrical Resistivity Tomography (ERT) is an advanced geophysical method used to determine the subsurface 's resistivity distribution by making measurements on the ground surface. ERT profiles consist of a modeled cross-sectional (2-D) plot of resistivity (Qm) versus depth. ERT interpretations, supported by borehole data or alternate geophysical data, accurately represent the geometry and lithology and/or hydrology and/or petrology, of subsurface geologic formations.

ERT data arc collected with an-automated multi-electrode.resistivity meter. Usually an array of 64 electrodes is used. An external source of power such as a 12v storage battery is required. The equipment contains an acquisition and processing software.

4..Refraction Microtremour -ReMi

This method makes use of the ambient noise or microtremours to map the shear wave velocities of the underlying strata. This is an indirect method for estimation of shear wave velocity. For proper design of earthquake resistant structures a fairly good estimation of ground amplification and acceleration is required. By estimating the shear wave velocity of subsurface strata the liquefaction analysis of soil strata and dynamic analysis of structures can be done.

The instrument used is a multichannel (24 or 12 channel) geophone (8 to 12 Hz) seismic refraction equipment. The equipment contains an acquisition and processing software.

5.Seismic Refraction Tomography

This method is based on the fact that seismic waves have different velocities in different types of soils (or rock) and besides the wave refract when they cross boundaries between different types of soils. In this method, an artificial impulse is produced either by detonation of explosive or mechanical blow with a heavy hammer at ground surface or at a shallow depth within a hole. Based on this from analysis the longitudinal waves, the thickness different soil strata are determined as also their density. The zone of saturation can also be worked out from the difference in velocities. The instrument used is a multichannel (24 or 12 channel) geophone (4 to 12 Hz) seismic refraction equipment. For concrete and masonry structures the frequency of the geophones should be the order of 40 to 60Hz. An instrumented hammer or mechanical hammer also forms part of the equipment. The disturbance is produced with this hammer. The equipment contains an acquisition and processing software.

III. PRELIMINARY STUDY DATA ACQUISITION&PROCEDURE

Peliminary study done at dam by visual observation and measuring quanity of water leakage by ventury meter which Can be used for measuring flow rates of water, gases ,suspended solids, slurries and dirty liquids. The figures shows the internal leakages of the dam. Also studied about convention methods to slow down the leakage.

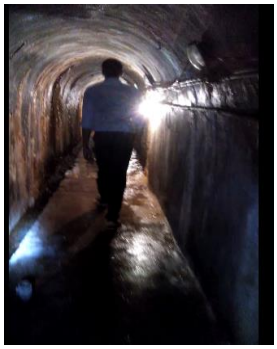


Fig.1. Dam gallery

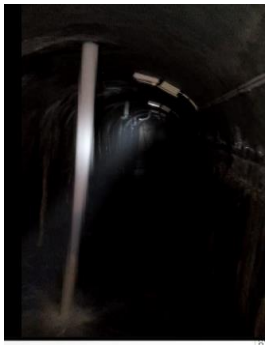


Fig.2. Major leakage 1

Fig.3. Major leakage 2

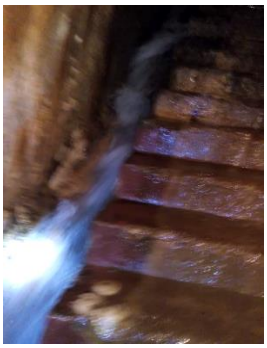


Fig. 4. leakage flow

IV. DATA ACQUISITION&PROCEDURE

Data acquisition of peruvannamuzhi main dam And its 13 subsidiary earth dams has done.

In GPR ,A series of scans are performed within an orthogonal survey grid. If any anomalies are detected the location and depth are marked on the surface and reviewed. Data is collected in control units.

Fig.5. GPR test on peruvnnamuzhy earth dam

In SP , Great care should be taken in acquiring and interpreting SP data, so that the characteristic fields associated with artificial noise sources are recognised.SP measurements require only two electrodes, a millivoltmeter and the cables to connect them. There are two different field procedures for SP investigations: gradient and absolute potential. I adopted Gradient Method.For the gradient method a dipole with a constant electrode separation (*l*) is moved along the survey area. If *l* is not too great then the ratio of the potential difference to length, measures the potential gradient. The absolute potential can be obtained by summing the potential differences along the profile; however the value obtained would contain the accumulated noise from each individual measurement. This can be reduced somewhat by 'leapfrogging', where the forward electrode becomes the rear electrode for the next measurement and only the rear electrode ever moves forward. Care must be taken in recording the polarity of each measurement when using this technique.

Fig.6. Streaming potential test

In ERT, The steel electrodes (64 numbers) are inserted into the ground at one meter spacing keeping the resistivity apparatus in the middle of the array. The method consist of injecting measured current into the ground through pairs of electrodes and measuring the electrical potential difference using another pair of electrodes in between. It typically uses an array of 64 electrodes connected by multi core cables which provides a section of the variation of resistivity laterally (along the line of electrodes) and vertically (depth wise)Switching of the current electrode pairs and the potential electrode pairs is done using a relay box automatically. The software for data acquisition keeps the spacing between the electrodes fixed and moves the pairs along the same line until the last electrode is reached. There after the spacing is increased and the procedure repeated creating a profile resistivity Vs depth along the survey line.

Fig.7. Data acquasation of ERT method

The use of electrodes which penetrate the surface to inject current or to measure voltage can be suitable where the surface is earth, for example in natural ground or embankment^ the surface of the ground is undisturbed, in such cases, the insertion of electrodes into the ground is not usually problematic. However, where the surface of interest is a built structure, such as a paved road, pavement, bridge, building or the like, it may not be possible or desirable to insert electrodes into the surface of the structure. Inserted electrodes may not have a good galvanic contact and may weaken and/or disfigure the surface.A known method to measure resistances whilst avoiding the insertion of electrodes into a surface uses the phenomenon of capacitive coupling to induce an alternating current in a sub surface material. The alternating current is induced by two capacitively coupled signal input electrodes and the resultant voltage due to the resistance of the subsurface material is detected by two capacitively coupled voltage detection electrodes. Using capacitively coupled electrodes, it is not necessary to insert the electrodes into the surface. Instead, the electrodes can be placed near to the surface. An electrode array can therefore be readily scanned over a surface of interest to build up a scan of the resistivity of an array of subsurface volumetric elements.

In ***ReMi*** data acquisition procedure consists of obtaining five to ten 20-second seismic noise records using conventional seismograph and P-wave geophones. The data is recorded using natural noise, by making people run along the seismic profiles, by making people jump at various points of the profile, by tapping of hammer at one end of the profile etc. The effort is to generate as much as random noise as possible in various ways.ethod makes use of the ambient noise or microtremours to map the shear wave velocities of the underlying strata

Fig.8. Data acquasation of ReMi method

In **SRT,** A standard seismic refraction line is laid out using 24 geophones at 5m intervals. Energy is input into the ground at various points located along the seismic line, resulting in a 2D velocity model of the subsurface.

A minimum of seven shot points are used for each spread. These include two far shots on either side of the spread, to provide the true seismic velocity of the "sound" rock, two end shots to obtain reciprocal times, and three mid shots within the profile to obtain lateral velocity variation in the top layer(s) (overburden).

The length of geophone spread depends upon the required depth of investigation and the dimensions of any subsurface features that are to be mapped. A length of approx. three to four times the depth of investigation is used. A geophone spacing of 5 m with 24 channels spread is adequate for detailed mapping of subsurface conditions to a depth of approx. 30m. The geophone spacing can be further increased for greater depth of investigation, if required**.**

Fig.9. Data acquasation of SRTmethod

V. INTERPRETATION AND RESULT

GPR survey is conducted to identify shallow cracks, cavities and voids in the dam body. The survey also might reveal the stratigraphy in the dam body based on contrast in dielectric constant. Following picture shows a cavity noticed by GPR.

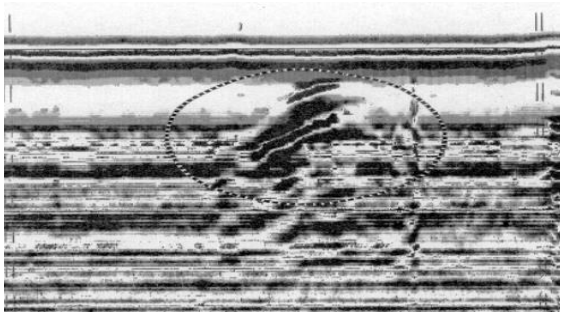


Fig.10. Cavity noticed by GPR.

Interpretation of SP measurements to infer seepage patterns and concentrated seepage flows ranges from simple qualitative to more advanced quantitative numerical modelling approaches. Most common application of SP study is to identify the zones in the dam body through which seepage is taking place. The results are correlated with resistivity sections as shown in figure11

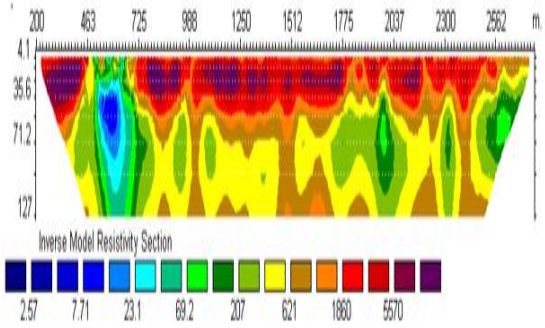


Fig.11. SP results correlated with resistivity

In ERT,the modelled results are displayed as scaled resistivity-depth pseudosection as illustrated below. Blues represent areas of low resistivity whilst reds are relatively higher. The wedge shape of the plot illustrates the gradual reduction in the amount of data acquired as the current and potential electrode spacing are increased

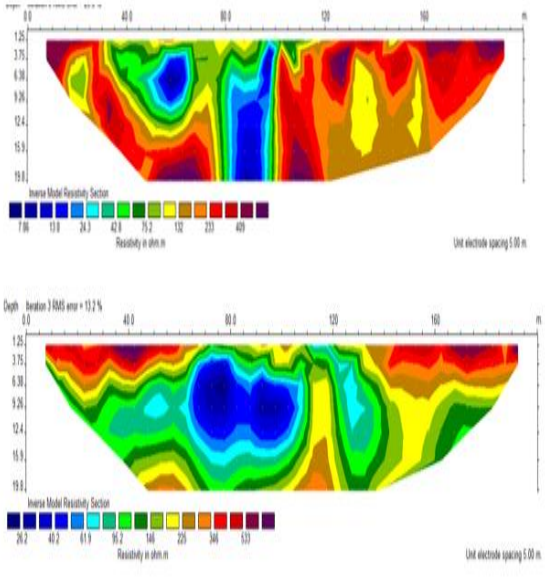


Fig.12. ERT results

The seismic refraction method detects changes in lateral- seismic velocity and/or layer thickness. Seismic techniques are extremely useful since seismic velocity is generally the most sensitive to slight changes in density and saturation in the types of materials commonly used in dams . Seismic Tomography is conducted between a pair of boreholes or between upstream and downstream face of the Dam, to provide high resolution details of internal structure. The resulting tomogram shown physical property of each unit cell of dam body. In a concrete dam the information can be interpreted in terms of fractures, weathered concrete etc., as shown in example hereunder:

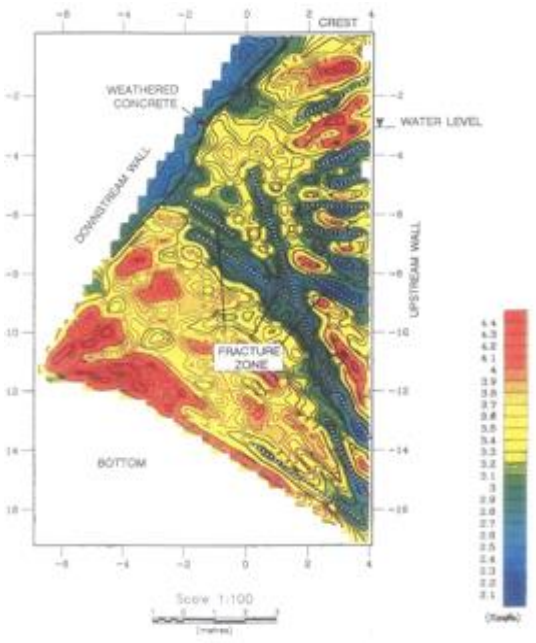
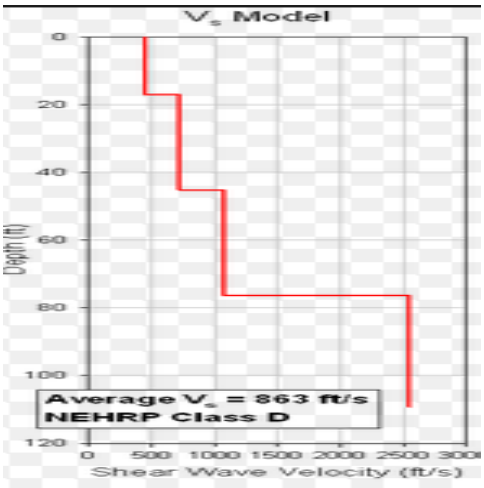


Fig.13. SRT result

The ReMi result of one earth dam shown below is have an average velocity of 863m/s .which comes under class D according to NEHRP



VI. REMEDIAL MEASURES

It is noticed that only allowable seepages in main dam but it is very necessary to provide proper maintance for preventing the dam from serious problems can happen later. Some earth dams found small cavity as well as one dam noticed pipe leakage. Bonding with epoxies, Grouting ,Routing and sealing can use as remedial measures. Here I studied about xypex products as remedial measure. Xpex is Canadian company which is manufacturing water proofing chemicals with new crystalline technology. It is very new product in to Kerala state. So I done experiments in the XYPEX CONCENTRATE,XYPEX ADMIX C-2000 NF and XYPEX MEGAMIX Xypex is a unique chemical treatment for the water- proofing, protection and repair of concrete.

XYPEX CONCENTRATE is the most chemically active product within the Xypex Crystalline Waterproofing System. When mixed with water, this light grey powder is applied as a cementitious slurry coat to above-grade or below-grade concrete, either as a single coat or as the first of at wo-coat application. It is also mixed in Dry-Pac form for sealing strips at construction joints, or for the repairing of cracks, faulty construction joints and honeycombs. Xypex prevents the penetration of water and other liquids from any direction by causing a catalytic reaction that produces a non-soluble crystalline formation within the pores and capillary tracts of concrete and cement-based materials.

XYPEX ADMIX C-2000 NF is added to the concrete mix at the time of batching. Xypex Admix C-2000 NF consists of Portland cement and various active, proprietary chemicals. These active chemicals react with the moisture in fresh concrete and with the by-products of cement hydration to cause a catalytic reaction. This reaction generates a non-soluble crystalline formation throughout the pores and capillary tracts of the concrete that permanently seals the concrete and prevents the penetration of water and other liquids from any direction.

XYPEX MEGAMIX II is a thick repair mortar for the patching and resurfacing of deteriorated concrete. Megamix II has been specifically formulated to produce superior bond, low shrinkage, chemical durability and high strength. It is a one component mortar and can be either sprayed or trowel applied at a thickness of 3/8" to 2" (10 mm to 50 mm). The high performance characteristics of Megamix II are enhanced by Xypex's uniquecrystalline waterproofing and protection technology

For experimental results compressive strength , permeability test and water absorption test has done on normal concrete cube as well as xypex applied concrete cubes. Results found that application of this material is acceptable for rehabilitation .

VII. CONCLUSION

Geophysical Techniques can use for Quick assessment of subsurface conditions of Dams in non-destructive manner. This techniques are important tool for health check of dams, regular monitoring and pre & post rehabilitation inspections. Experimental study conducted on kuttiyadi project and It is noticed that only allowable seepages in main dam but it is very necessary to provide proper maintance for preventing the dam from serious problems can happen later. Experimental study done on the application feasibility of Xypex in existing dam found satisfactory.

REFERENCES

[1] Abuzeid, N. (1994). "Investigation of channel seepage areas at the existing Kaffrein Dam site (Jordan) using electrical-resistivity measurements." Journal of Applied Geophysics, 32,163□175.
[2] Barker, R. and Moore, J. (1998). "The application of time-lapse electrical tomography in groundwater studies." Leading Edge, 17, 1454□1458.
[3] Bentley, L. R. and Gharibi, M. (2004). "Two- and three-dimensional electrical resistivity imaging at a heterogeneous remediation site." Geophysics, 69, 674□680.
[4] CGS (Central Geological Survey) (1998). Explanatory Text of the Geologic Map of Taipei (1:50,000), Ministry of Economic Af-fairs, Taipei, Taiwan (in Chinese).
[5] Cho, I. K. and Yeom, J. Y. (2007). "Crossline resistivity tomography for the delineation of anomalous seepage pathways in an embankment dam." Geophysics, 72, 31□38.
[6] Dahlin, T. and Leroux, V. (2006). "Time-lapse resistivity investigations for imaging saltwater transport in glaciofluvial deposits." Environmental Geology, 49, 347□358.
[7] Dahlin, T. and Zhou, B. (2004). "A numerical comparison of 2D resistivity imaging with 10 electrode arrays." Geophysical Prospecting, 52, 379□398.
[8] Friedel, S. (2003). "Resolution, stability and efficiency of resistivity tomography estimated from a generalized inverse approach." Geophysics Journal International, 153, 305□316.
[9] Geotomo Software (2002). RES2DMOD Ver. 3.01, Rapid 2-D resistivity forward modeling using the finite-difference and finite element methods, available at www.geoelectrical.com.
[10] Griffiths, D. H., Turnbull, J., and Olayinka, A. I. (1990). "Two-dimensional resisitivity mapping with a computercontrolled array." First Break, 8, 121□129.
[11] Johansson, S. and Dahlin, T. (1996). "Seepage monitoring in an earth embankment dam by repeated resistivity measurements." European Journal of Engineering and Environmental Geophysics, 1, 229□247.
[12] Karastathis, V. K., Karmis, P. N., Drakatos, G., and Stavrakakis, G. (2002). "Geophysical methods contributing to the testing of concrete dams, application at the Marathon Dam." Journal of Applied Geophysics, 50, 247□260.
[13] Kim, J. H., Yi, M. J., Song, Y., Seol, S. J., and Kim, K. S. (2007). "Application of geophysical methods to the safety analysis of an earth dam." Journal of Environmental and Engineering Geophysics, 12, 221□235.
[14] Lee, J. Y., Choi, Y. K., Kim, H. S., and Yun, S. T. (2005). "Hydrologic characteristics of a large rockfill dam: Implications for water leakage." Engineering Geology, 80, 43□59.
[15] Lim, H. D., Kim, K. S., Kim, J. H., Kwon, H. S., and Oh, B. H. (2004). "Leakage detection of earth dam using geophysical methods." Proceedings of the 72th Annual Meeting of International Com-mission on Large Dams (ICOLD), 212□224.
[16] Malkawi, A. I. H. and Al-Sheriadeh, M. (2000). "Evaluation and rehabilitation of Dam seepage problems. A case study: Kafrein dam." Engineering Geology, 56, 335□345.
[17] Nguyen, F., Kemna, A., Antonsson, A., Engesgaard, P., Kuras, O, Ogilvy, R., Gisbert, J., Jorreto, S., and Pulido-Bosch, A. (2009). "Characterization of seawater intrusion using 2D electrical im-aging." Near Surface Geophysics, 7, 377□390.
[18] Oh, Y. C., Jeong, H. S., Lee, Y. K., and Shon, H. (2003). "Safety evaluation of rock-fill dam by seismic (MASW) and resistivity method." Proceedings of the 16th Annual Symposium on the Application of Geophysics to Engineering and Environmental Problems, 1377□1386.
[19] Okko, O., Hassinen, P., and Korkealaakso, J. (1994). Location of Leakage Paths Below Earth Dams by Geophysical Techniques: Proceedings of the 13th International Conference on Soil Me-chanics and Foundation Engineering (ICSMFE), 1349□1352
[20] Oldenborger, G. A. and Routh, P. S. (2009). 'The point-spread func-tion measure of resolution for the 3D electrical resistivity experiment." Geophysical Journal International, 176, 405□414.
[21] Oldenburg, D. and Li, Y. (1999). "Estimating the depth of investiga-tion in DC resistivity and IP surveys." Geophysics, 64, 403□416.
[22] Panthulu, T. V., Krishnaiah, C., and Shirke, J. M. (2001). "Detection of seepage paths in earth dams using self potential and electrical resistivity methods." Engineering Geology, 59, 281□295.
[23] Song, S. H., Song, Y., and Kwon, B. D. (2005). "Application of hydrogeological and geophysical methods to delineate leakage pathways in an earth fill dam." Exploration Geophysics, 36, 92□96.