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Electromagnetic Survey of Erosion in Awba, Ibadan, Nigeria Embankment Dam

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ABSTRACT *- The study was conducted to find possible leakages associated with dams as well as finding mitigation measures to reduce dam failures. The Very Low Frequency Electromagnetic (VLF-EM) equipment was used to measure the conductivity of the subsurface at a spacing of 5m and 10m. The measured data were converted to filtered real data using a filter operator. Linear features presumed to be fractures were inferred from the VLF-EM profile. These fractures were less than 9m in depth. In all, eight local positive peak amplitudes depicting areas of high conductivity and suggesting possible areas of seepages were identified on the filtered (EM) response. The results suggest internal erosion at distances of 72m, 80m, 85m along traverse 1 and 25m, 30m, 33m, 70m and 82m along traverse 3 from the spillway. Based on these results, it's therefore necessary to embark on mitigation measures such as replacements of the rock slabs and removal of the underlying mud sediments to enhance the longevity of the dam.*
Key Words*: Electromagnetic, Fractures, Conductivity, Seepage, Erosion, Embankment*

I. INTRODUCTION

Embankment dam comes in two types; the earth filled made of compacted earth and rock filled dam (U.S Bureau of Reclamation, 2000). Dams are classified by its functions and structure/design (British Dam Society, 2004; Dam safety office, 2010; Arch dam forces, 2007). Dam failures are generally catastrophic if the structure is breached or significantly damaged (Olorunfemi et al, 2005; Wikipedia, 2012).The main causes of dam failures include; inadequate spillway capacity, piping through the embankment, foundation or abutments, spillway design error, geological instability, poor maintenance, extreme rainfall and human error(Yilmaz, 2012; Singh et al, 2003; Foster et al, 2000).

Internal erosion is a major cause of failures in embankment dams (Sjodahl et al, 2004). The seepage flow increases slowly, closely coupled to material transport that can take place over a long time (American Society of Civil Engineers, 2000). This problem can easily be detected by a monitoring system that has both high accuracy and a high resolution. Development of geophysical methods during the last decade has increased the use of such methods for dam investigation (Fargier et al, 2010; Sheffer, 2002; Sjodahl, 2006). Furthermore, the demand for monitoring is not the same as investigation (Sjodahl, 2006). Experience from field measurements has further focussed on the need of a better physical understanding of the basic process and how all the fundamentals parameter interacts. The monitoring aspects of the fundamental internal erosion processes in a dam have been found more complicated than many other applications for the same method (Aufleger, 2004; Sam Johnson, 2005; Sjodahl, 2006). Seepage can emerge anywhere on the downstream face, beyond the toe, or on the downstream abutments at elevation below normal pool. It may vary in appearance from ''soft'' wet area to a flowing ''spring" (New York State Department of Environmental Conservation, 2003). Seepage can make inspection and maintenance difficult and also saturate, weaken positions of the embankment and foundation, making the embankment susceptible to earth slides (National Dam Safety Program Research 2006; Fell et al, 2007; Johansson et al, 2001; Kofoed et al, 2006).

Several Swedish projects were carried out in the late 80ties to date in Sweden and across the world in order to find appropriate methods to detect seepage changes and internal erosion (Johansson et al, 1995). A general study of possible non-destructive methods identified temperature, resistivity and Streaming Potential (SP) as the most appropriate methods to study internal erosion and seepage (Singh et al, 2003). Those methods have since 1993 been applied in several dams for long term monitoring (Johansson et al, 1995). Extensive research within this field have also been carried out in several other countries especially Germany, US, Canada, and South Korea (Sjodahl, 2006; Sam Johnson, 2005; Sjodahl et al, 2004; Johansson et al, 2000; Johansson et al, 2003; U.S Bureau of Reclamation, 2000; Razicki et al, 2010; Cote et al, 2007; Association of State Dam Safety, 2003; American Society of Civil Engineers, 2000).

This area concerned is an earth dam located in the South Western fringe of the University of Ibadan, Nigeria. Its catchment area shows evidence of high degree of fracturing; a significant volume of impounded water is probably lost through these fractures. The dam embankment is founded on fairly thick of 14.2m weathered layer with tendency for reservoir water seepage from beneath. Based on this, a broad investigation is adopted on the structure for seepage zones.

II. GEOLOGY OF STUDY AREA

Awba Dam is underlain by the metamorphic rock types of the basement complex with few intrusions of granites and porphyries of Jurassic age. The major rock types are the quartzite of the meta-sedimentary series and migmatite-gnesis complex comprising of migmatites, banded gneisses and augen gneisses. The minor rock types include the intrusions such as pegmatite, quartz, aplite, diorites and amphibolites as well as dissolved Xenoliths. These rocks strikes along the north direction with an average dip of 50^0W and 30^0E (Amusa, 1993).The dam falls in between latitude 7^0 27N and 7^0 29N and longitude 4^0 53E and 4^0 54E and at an altitude of 185m above sea level (Tyokunbur et al, 2002; Akin-oriola, 2003).The climate of the area complies with the tropical rainforest climate having two distinct conditions. The rainfall is about 1262mm per annum while the temperature ranges between 27^0 C and 29^0C (Abdel-Azim et al, 1996).

III. METHODOLOGY

Electromagnetic method is classified into four, which includes; Continuous Field method, Transient Field method, Magno-telluric method and Very Low Frequency method. These methods involve the use of electromagnetic waves which are coupled with alternating electric intensity and a magnetizing force as established Parasinis (1986). Their application in geological studies is based on the response of the ground to their propagation and they have proven useful in probing lithologies of varying conductivities, detecting ores that form good conductors, fractures and crushed rocks bearing conductive water (Abdel-Azim et al, 1996). The very-low frequency electromagnetic method was used based on ABEM (1990) principle. This involves the passage of time varying low frequency primary EM-fields into the subsurface which in turns generate secondary electromagnetic fields within the subsurface. These secondary EM-fields are detected by the alternating current they induce to flow in a receiver coil by the process of electromagnetic induction. The presence of the conductive body will cause the electromagnetic field penetrating or travelling through the ground to induce eddy current which flows through the conductor as well generating its own secondary electromagnetic fields are easily picked up by the receiver. These make use of very powerful transmitters which are not built within the machine. These transmitters are external radio transmitters that are used by military men in communicating with submarines. They produce magnetic field lines that are horizontal circles which expand away from the aerial as waves travelling at the speed of light thereby producing aligned concentric circles of field lines around the transmitter's antenna.

Benefits of Very Low Frequency Electro-magnetic Method

1. No physical contact is required either between the transmitter and the receiver or the ground surface hence, it can be used when conductive ground connection is not possible owing to highly resistive or insulating surface formations such as the polar or sub Polar Regions.
2. The method is fast and easier than others.
3. It requires lesser man power, only one operator and a recorder.
4. It can be done within limited space and rugged terrains unlike the electrical methods.

Limitations of electro-magnetic method

1. There is problem of distinguishing between a large conductor at great depth and a smaller conductor at shallow depth from the plot.
2. Subsurface conductive bodies with the same thickness and conductivity may likely give similar electrical equivalence.
3. Deeper conductors which are real objects of exploration may be screened out to become undetectable due to secondary current produced in superficial overburdens of good conductivity e.g. clays, graphitic, shale etc.

IV. RESULTS AND DISCUSSION

The interpretation processes are both qualitative and quantitative techniques. Electromagnetic systems are sensitive to near surface conductivity variations especially where high conductivity regoliths clay are present. Since the vertical and horizontal dipole coil systems respond differently to near surface charges in conductivity only a qualitative interpretation of ground conductivity profile is carried out. The partial curve matching method involving two-layer master curve and the corresponding auxiliary curves were employed in carrying out the quantitative interpretation of the sounding curves.

The very low frequency data was interpreted based on the relationship between the real and imaginary curves. The points of crossing or maximum difference between the real and the imaginary curves are interpreted as anomalous/fractured zones (olorunfemi et al; 2005).This gives an indication of zones of relatively high conductivity. These zones are likely to be fractured or weathered zones. Occasionally, the fracture serves as conduit for groundwater movement and subsequent accumulation.

In this survey, zones with relatively high conduit were identified and this was due to the fact that the crossover point and maximum displacement between real and imaginary indicates an area of fractured zones which serves as space for ground water accumulation. These fractured zones are located at stations 72m,80m,85m along the traverse 1 and 25m,30m,33m,70m and 82m along traverse 3.It can be deducted that 3 fractured zones were suspected along traverse 1 in S-N direction and 5 fractured zones along traverse 3 E-W direction. Therefore, 8 fractured zones were suspected. The results of the electromagnetic survey are presented in fig 1 to 6.

Fractured zones result into seepage which are normally due to piping and sloughing. Piping leads to dislodgement of particles from the soil structure leading to the re-arrangement of fines to void between larger particles. The internal erosion of soil mass eventually leads to the formation of an open conduit in the soil which may lead to failure of the embankment/dam.

Magno-telluric method, metal detection and electrical resistivity method could be used to confirm the results obtained. Similarly, grouting, installation of upstream blanket or installation of relief wells should be used to control the quantity of internal erosion. Mitigation measures as replacement of rock slabs and removal of underlying mud sediments are necessary at the embankment to enhance good drainage facilities and most importantly, the longevity of the dam.

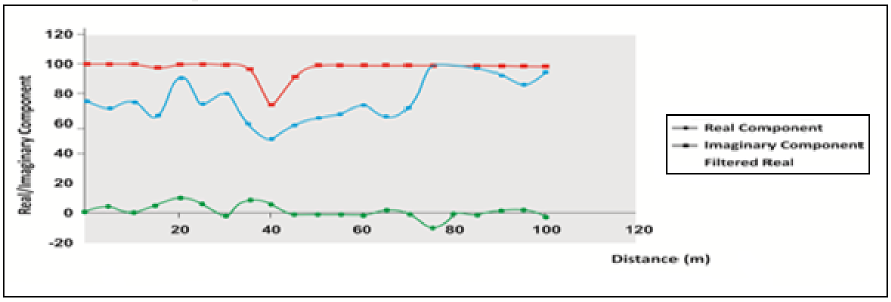

Fig 1: Electromagnetic (VLF) Conductivity Profile along traverse1, S-N direction at 5m interval

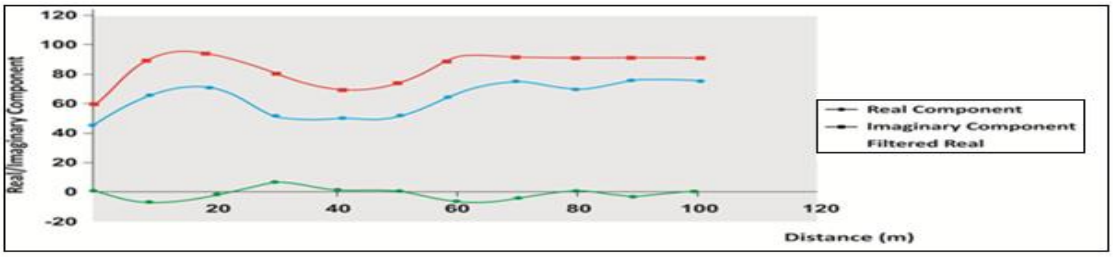

Fig 2: Electromagnetic (VLF) Conductivity Profile along traverse1, S-N direction at 10m interval

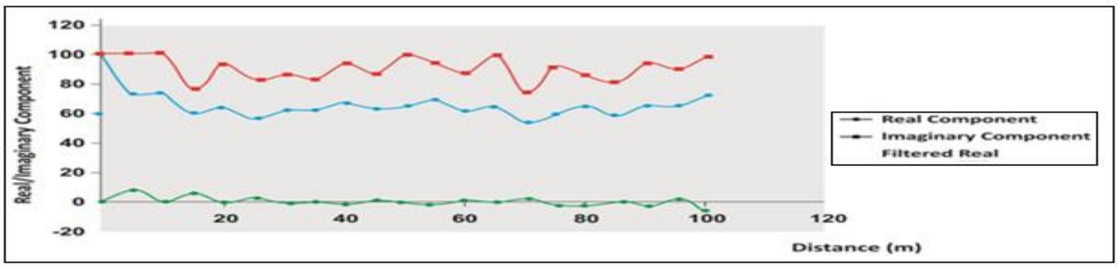

Fig 3: Electromagnetic (VLF) Conductivity Profile along traverse2, E-W direction at 5m interval

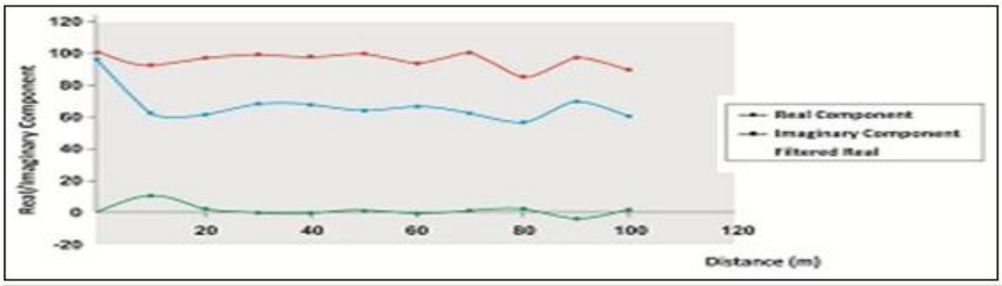

Fig 4: Electromagnetic (VLF) Conductivity Profile along traverse2, E-W direction at 10m interval

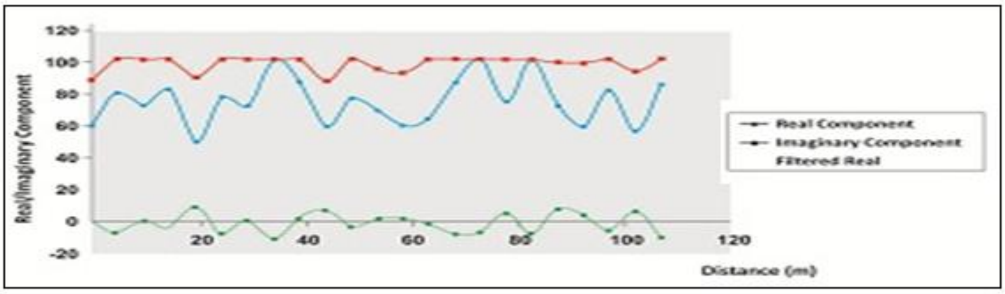

Fig 5: Electromagnetic (VLF) Conductivity Profile along traverse3, E-W direction at 5m interval

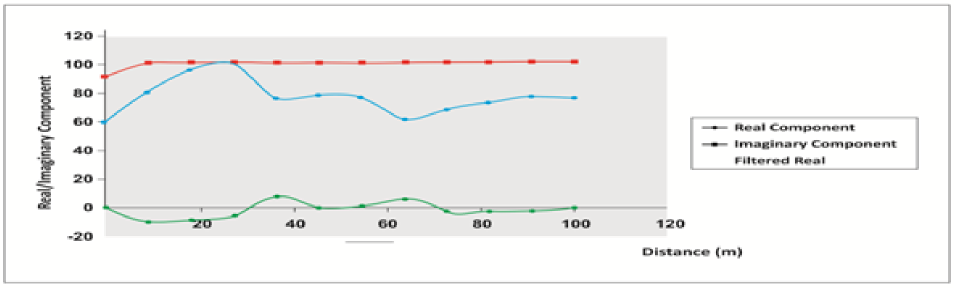

Fig 6: Electromagnetic (VLF) Conductivity Profile along traverse3, E-W direction at 10m interval

V. CONCLUSIONS

The electromagnetic very low frequency was carried out on Awba dam and data was acquired along 3 traverses. Both the maximum difference and points of crossover between the real and imaginary curves were used to delineate the shared /fractured and weathered zones which were identified as areas of fracture and possible areas of internal erosion.

The result of the study suggests that electromagnetic very low frequency method is an adequate method of monitoring seepages in embankment dams. The point of crossover between the real and imaginary components was used to delineate the fractured zones which were identified as areas of fracture and possible internal erosion. Internal erosion was suspected a long distance 72m, 80m, 85m along traverse 1 and 25m, 30m, 33m, 70m and 82m along traverse 3 from the spillway. The Awba dam embankment is permeable which confirm internal erosion in the embankment. Thus, internal erosion is a factor responsible for dam failure.

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