Georadar Application for Dam Safety Study (Case Study of Selorejo Dam)

Teguh Winari[1], Kamsiyah Windianita[1], and Fahmi Hidayat[1]

Abstract* – Selorejo dam is located on the river of Kali Konto near Ngantang, a district in the western part of Malang Regency, East Java, Indonesia. The dam was built in 1963 as rockfill dam type with impervious and shell zone that consist of gravel and sandstone. As time goes by, the dam will be going to deteriorate and increasing worries regarding to its safety. One of the problems that generally related to the dam safety is the water seepage. It may cause internal erosion that later can trigger dam collapse. During construction period, the water seepage in Selorejo dam happened significantly and had been repaired by clay blanket in downstream slope and embankment in upstream slope for counterweight. In 1995, there was sizeable and clean water seepage located in the middle of downstream slope, about 100 m from contact area between the downstream slope and the left pedestal hill. Therefore, in 2015 Jasa Tirta I Public Corporation (PJT I) conducted Ground Penetration Radar (Georadar) testing as preliminary study in the seepage area to determine the future treatment. The georadar measurement in Selorejo dam consisted of 14 longitudinal and 7 transversal paths with the antenna frequency of 270 MHz. The result of georadar measurement was a radargram with variant colors; bright one shows a layer with relatively higher density, while the dark one shows a layer with relatively lower density or weak zone. It revealed that there are no layer with extreme density difference in Selorejo dam. The recorded anomaly is a usual layer discontinuity found in soil embankment.

***Keywords* – Dam, seepage, georadar, anomaly**

I. Introduction

Selorejo dam is located on Konto river near Ngantang, a district in the western part of Malang Regency, East Java, Indonesia (Figure 1). Selorejo dam is a zoned fill type dam which constructed in 1963 until 1970. As a multipurpose dam, Selorejo dam is expected to control the flood to such extent that the peak of design flood 920 m^3/second will be reduced to 360 m^3/second, supplement the discharge in dry season by about 4 m^3/second in average. It can expand the irrigation area to be 5,700 ha and increase the rice production of about 7,500 ton/ year. The discharge also increase the power to be generated through the existing power station about 30,000 MWH per annum and eventually produce an electric power of about 20,000 MWH per annum through a new generating unit of 4,500 kW in the maximum capacity upon the completion of installation.

Considering that Selorejo dam has a high risk and the existing of permeable sandstone layer in the dam foundation, it is very important to analyze of seepage behavior related to dam safety level. Seepage in a dam leads to internal erosion process in short period without beeing preceded by visual signs on the dam surface. In some dams, there is sinkhole that can appear suddenly on the dam surface without initial visual signs. This dam safety analysis can be interpreted more quickly and properly to determine future action in dam operation and maintenance.

The left pedestal of Selorejo dam is a part of dam having problems during construction period, like water seepage. The water seepage in Selorejo dam happened significantly in 1995 and had been repaired by clay blanket in downstream slope and embankment in upstream slope for counterweight. There is still sizeable and clean water seepage located in the middle of downstream slope, about 100 m from contact area between downstream slope and left pedestal hill. In 2015 PJT I conducted Ground Penetration Radar (GPR) testing as a preliminary study in the seepage area. Georadar is one of geophysical methods which is developed as one of helping tools for subsurface geology research that is relatively shallow and detail. The principle of using this method is similar to the seismic reflection method and the penetration of this method much depends on electrical properties of the media that are investigated.

II. Method

Georadar is one of the geophysical methods that is developed as one of helping tools for subsurface geology research that is relatively shallow and detail. The technique of using georadar method is Electro-magnetic Subsurface Profiling (ESP) system, which is by utilizing the reflection of electromagnetic waves emitted by the soil surface by means of an antenna. The transmitting and returning of electromagnetic waves is relatively fast, which is in nanosecond of time. The work principle of georadar can be seen at Figure 2. The penetration depth of georadar method is highly dependent on the electrical properties of the investigated media, such as electrical conductivity and dielectric constant. Both electrical properties are closely related to physical properties of soil or rock, such as the water contents and its salinity properties. Based on experience, the ability of this georadar penetration tool may reach 25 - 30 m if it is used in an area with a relatively small salinity level.

The use of Georadar method for technical importance is in the form of data interpretation which is a georadar recorder, a geophysical helping tool that can describe shallow subsurface layer with high resolution and structure analysis of geological subsurface which can be attached to

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drilling data. To gain an optimal and directional result, it is necessary to do some research stages, which is preparation, data sampling, data processing, data interpretation, and report arrangement.

Stages of implementation activities of georadar measurement at Selorejo dam are as follows :

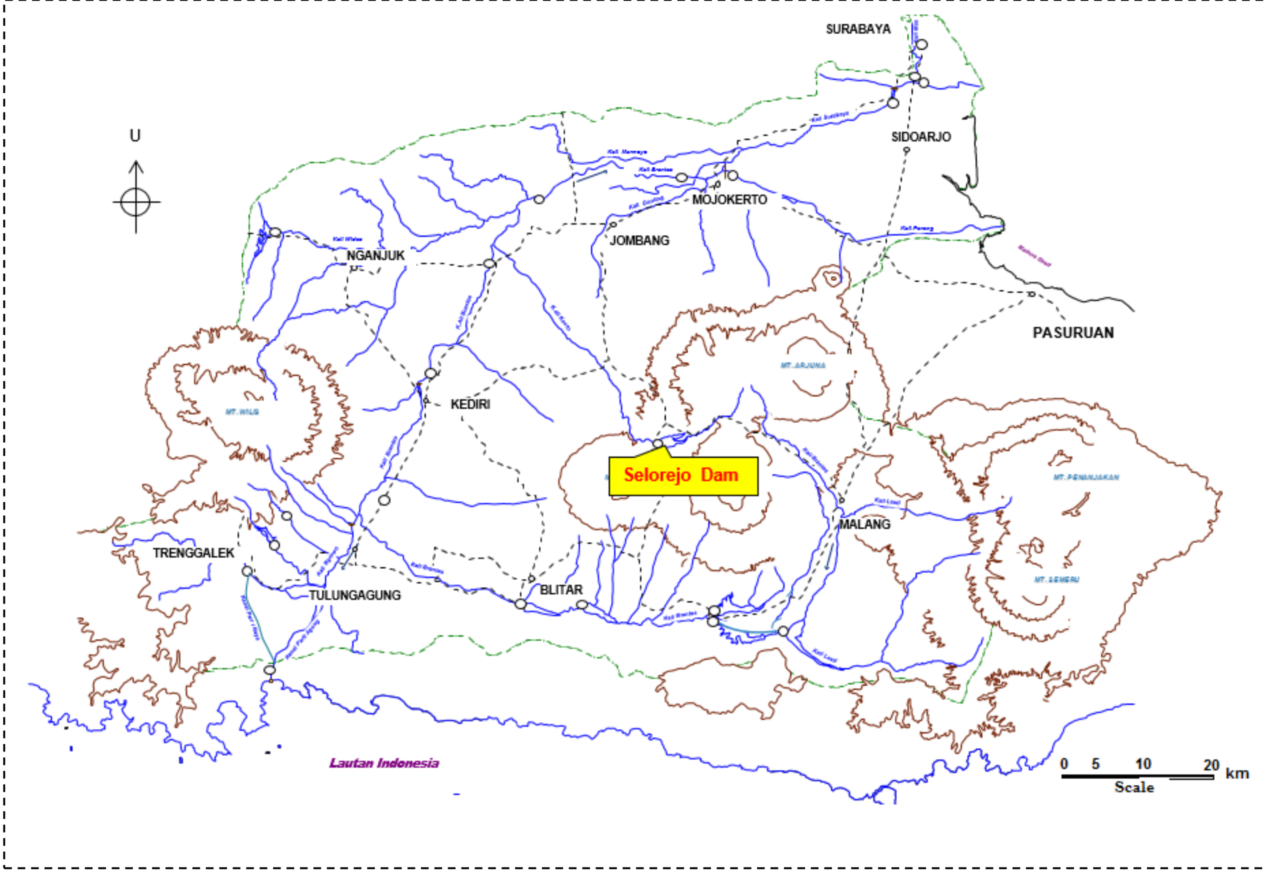

Figure. 1. Location of Selorejo dam

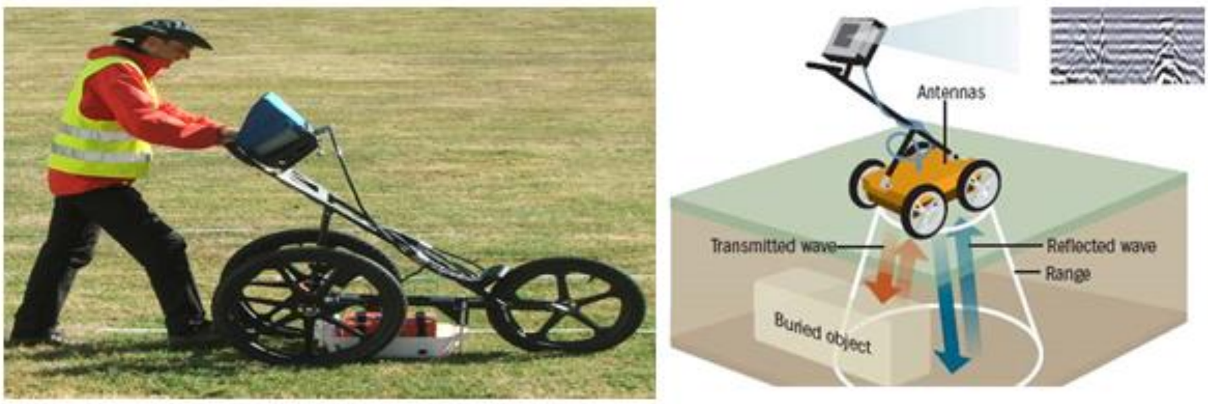

Figure. 2. The work principle of georadar

1) Determining the path to be measured
   Georadar measurement is conducted by dividing the work area into two kinds of path, including transversal and longitudinal paths. There are 14 longitudinal paths and 7 transversal paths. Sketch of the track can be seen at Figure 3 below.
2) The determination of the distance between the points will be reviewed on each tracks.
   In longitudinal path measurement taken used five meters distance between points from a start point. While, in the transversal path measurement used seven meters distance between points. After the location of the point that will be measured at each path are obtained, the points are marked in order to facilitate the measurements.
3) Georadar installation and measurement.Georadar antenna that is used is 270 MHz.

III. Result and Discussion

The result of georadar measurement in Selorejo dam is a radargram. Radargram describes a signal caused by a variation type of soil/ rock/ fluid, such as water seepage that is reflected on different conductance/ capacity value if it is compared to homogenous layer. With all different properties, the velocity of EM georadar wave as a displacement current will result a different amplitude as well. The attenuation, reflection, and signals dispersion properties also show the different 'structure' in subsurface. A contrast color difference in radargram will indicate the density level.

A. Longitudinal Direction of Georadar Path

The georadar measurement result of longitudinal path can be seen at Figure 4 and Figure 5. With a track measurement length of 32 m, georadar can detect until the depth of about 4 m. The radargram result on this soil stack shows a domination of layer discontinuities. This is due to material density variation that is displayed through bright colors, red and black. This bright color appears in all tracks with random spread and dominating that indicates a higher density than red and black area. The almost black and black colors show a weak zone. This weak zone is dominant on track C-C' and D-D' (white circle), and in other tracks it appears as small and local spots. The unconformity on some radargram does not indicate a structure. This thing is considering to measurement on stacks so the possibility is the discontinued layer.

B. Transversal Direction of Georadar Path

The measurement results of transversal path georadar A - N to A' - N' can be seen in Figure 6 through Figure 12, from the upper track point until track G. With a track measurement length of 36 m, georadar can detect until 3.5 m depth. The length of white vertical line on the surface to the next closest line is 3 m.

Radargram in transversal path shows the embankment material that is divided into two layers, with the inter-layer at a depth of 1.5 m. In one track there is upper part which is denser than the bottom, and some are otherwise. The denser top is described with a lighter color (purple-blue-green-yellow) located on the upper layer of 1.5 m, while the lower part is black or dark red. The are some weak zones (white circle) that is shown by georadar measurement result in transversal path :

a. A-N path (Figure 6), from point A to point C (about 15 m), around point I and point K
b. O'-O path (Figure 7), around the point H and L - M
c. P'-P path (Figure 8), random from point G2 to P
d. R-R' path (Figure 10), random from G4 to R
e. S'-S path (Figure 11), around point F5

There are also discontinuities (white line) on some tracks, such as track A-G, trajectory O'-G1, P'-G2 trajectory, trajectory Q'-G3, S'-G5 trajectory, and G5-S path. However, because the measurements are performed on the soil stack, discontinuities are not in the dam structure but it is less-well dense material.

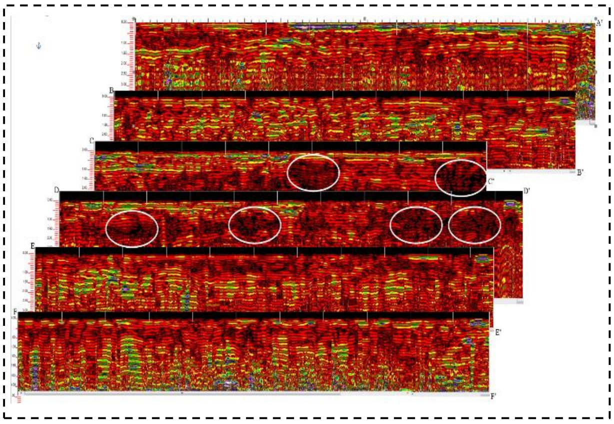

Figure. 4. The georadar measurement result of longitudinal path A - A' to F - F'

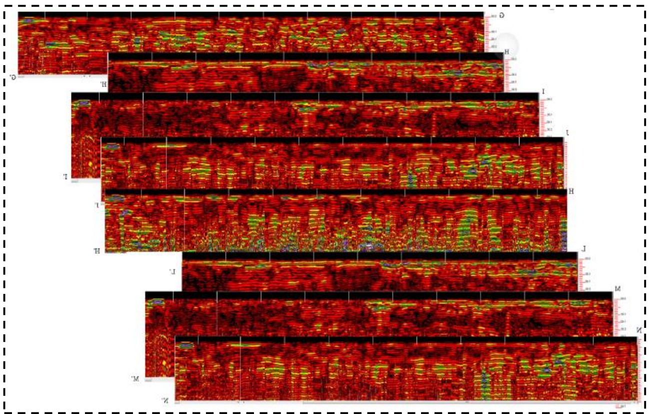

Figure 5. The georadar measurement result of longitudinal path H - H' to N - N'

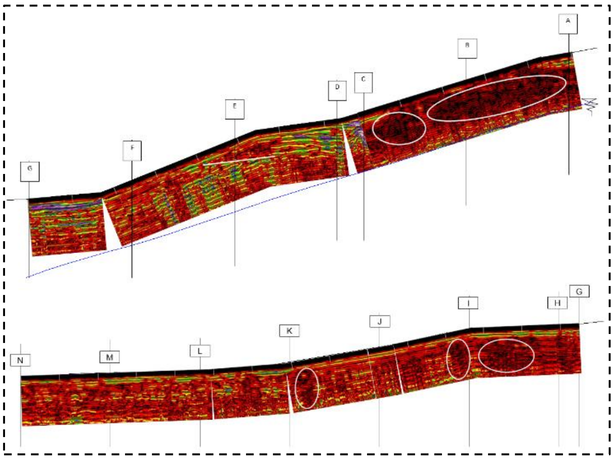

Figure. 6. The measurement result of transversal path A - N

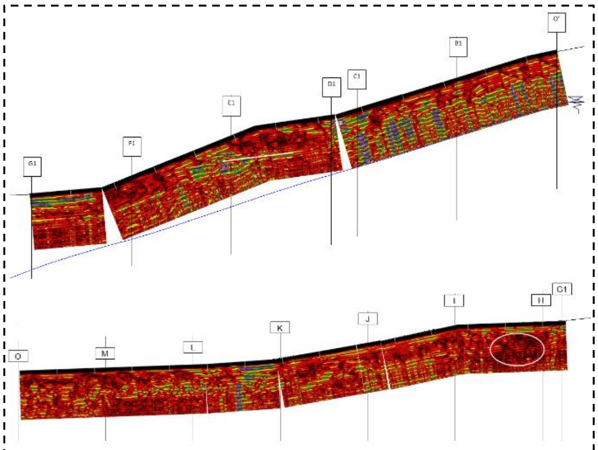

Figure. 7. The measurement result of transversal path O' - O

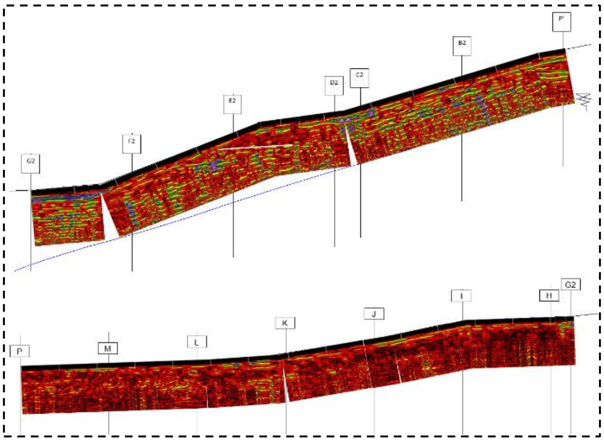

Figure. 8. The measurement result of transversal path P' - P

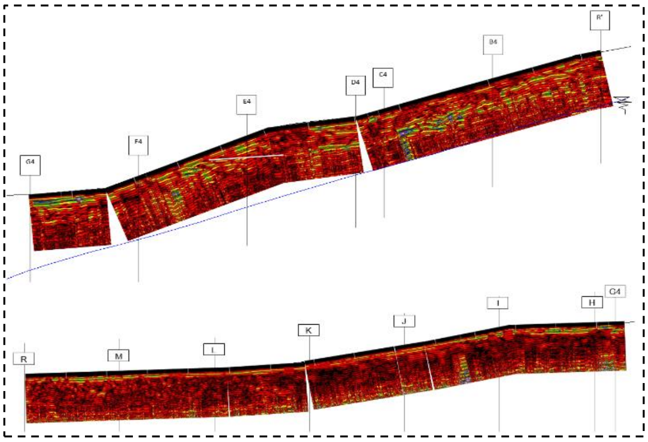

Figure. 10. The measurement result of transversal path R' - R

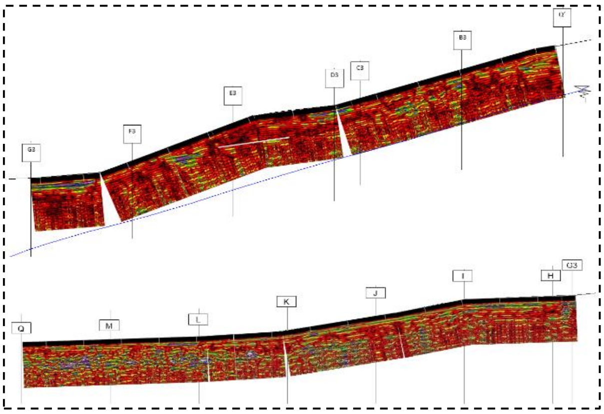

Figure. 9. The measurement result of transversal path Q' - Q

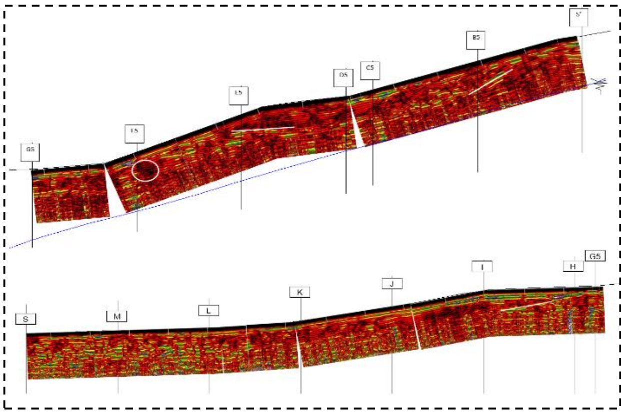

Figure. 11. The measurement result of transversal path S' - S

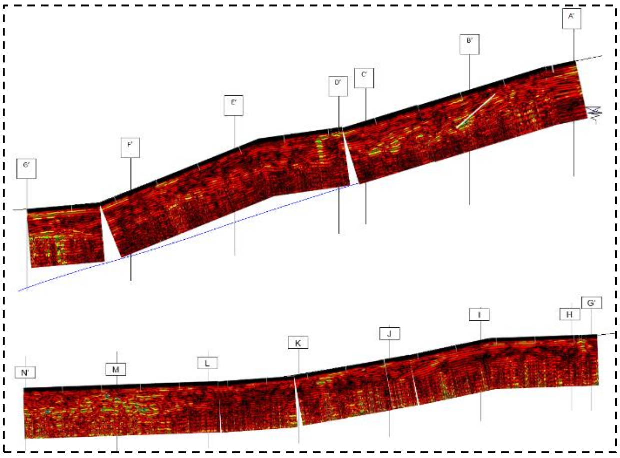

Figure. 12. The measurement result of transversal path A' - N'

IV. CONCLUSION

Based on the interpretation of georadar investigations were conducted and combined with the results of instrumentation and visual observations, it can be concluded as follows :

1) Georadar measurement at the left embankment of Selorejo dam consist of 14 longitudinal and 7 transverse paths (grid system). The measurement focused on area predicted as a seepage path and weak zone.
2) There are no extreme anomalies recorded at the left embankment of Selorejo dam. The usual anomalies recorded is layer discontinuities in the soil embankment. The density level of the materials is shown by color variation from bright (dense material) to dark colors (less dense material). The darks colors indicate as weak zone.

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