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Detection of Cavities in the Ground Using Georadar Technique

Mr. R. Obad[13], Mr. M. Afifi[1], Mr. H. Ait Benamer[2], Mr. O. Moudden[3], Mr. A. Salhami[4]

1. Department of Physics and Applications of the Faculty of Sciences Ben M'sik Casablanca Morocco
2. Office of Technical design ATLAS RADAR Casablanca Morocco
3. Laboratory of Structure & Rehabilitation Casablanca Morocco
4. Center of constructions Diagnosis in Casablanca Morocco

ABSTRACT: *The cavities in the soil are dangerous and they caused the deterioration, the collapse of many buildings, the subsidence and the decaying of the infrastructures. To this, the localization of voids by non-destructive methods such as GEORADAR method which is based on a scanning propagation of electromagnetic waves in the basement, is necessary, it helps to prevent and to take early measures and arrangements necessary to ensure the safety and the stability of the structures.This article discusses the comparison of the application of GEORADAR method with various antennas to usual common drilling as cored poll drilling. The results obtained by the regular cored drilling validate the authentication by Radar GPR technique with antennas of 400 MHz and 1.5 GHz*

I. INTRODUCTION

The existence of cavities in the basement is a prospective source of dangerous phenomena as regarding the stability of structures and infrastructures. It is well known that the characteristics of the basement play a lot on its strength and stability. The existence of these cavities and voids has already had a dramatic impact on the buildings and the infrastructures. As such, the specification of voids by non-destructive methods is still the only alternative to the usual destructive drillings that are still only occasional.

This article discusses the application of GEORADAR method that was tested on sites known by the existence of cavities in the subsoil. The results are compared to those obtained by destructive testing as the cored drilling.

II. PRESENTATION OF RADAR OF THE SOIL

The radar of the soil (also known as GPR or geological surface radar) is a method of geophysical exploration based on the propagation of electromagnetic (EM) waves of frequencies ranging from 1 to 3000 MHz. The electromagnetic waves are reflected or diffracted at the borders of objects that exhibit differences of electrical and / or magnetic characteristics. The dielectric permittivity, the electric conductivity and the magnetic permeability are the three physical petro parameters that specify the limits of reflectivity of layers and the profundity of the penetration.

First, we will identify the three petro physical parameters that are characteristic of the electromagnetic performance of environment. Then, we describe the equations that manage the propagation and the reflection of electromagnetic waves in a heterogeneous environment. We develop the case of the propagation of electromagnetic waves applied to the method of the soil radar.

III. EXPERIMENTAL SITE

It is about the foundations of an industrial building that the soles of the foundation are currently sitting on strongly altered and disintegrated sandstone that suffered a reduction in its original resistance. The subgrade has already undergone reinforcement by injections in order to fill the existing cavities.

The dissolution of the sandstone is caused by the artificial water coming from operating leakage. This sweet water (sugar syrup or sucrose) is trapped in the shale – sandstone interface, and by capillary action that causes the dissolution of sandstone, with time, the rock is disintegrated and crumbled, simply giving rise to cavities and voids.

For this purpose, several tests were achieved as follows:

- Drillings in foil and cored drilling
- Auscultation by the technique of Ground Penetrating Radar

IV. DRILLING OF SOIL RECOGNITION BY DRILLING(CORING).

The core drilling achieved by sounders permits the sampling of intact sample of the encountered layers
The results attained by the cored drilling realized by sounders are given in the table below

- **Cored survey°n 1**

profundity (m)	Soil structure
From 0.00m to 0.10m	Concrete paving
From 0.10m to 0.20m	Concrete
From 0.20m to 0.60m	embankment made of blocks and uncemented quartzite aggregates
From 0.60m to 0.1.40m	Concrete cement
1.40m to 1.60m	stones and quartzite aggregates
1.60m to 1.90m	Concrete cement
From 1.90m to 3.00.m	sandstone disintegrated and crumbled
From 3.00m to 5.80.m	strong Shale

- **Cored drilling°n 2**

profundity (m)	Soil formation
From 0.00m to 0.10m	concrete paving
From 0.10m to 0.65m	hedgehoging, uncemented aggregates and quartzite blocks
From 0.65m to 0.75m	altered sandstone
From 0.75m to 1.90m	very altered Sandstone , dissolution of the sandstone in sand
1.90 to 2.60m	Aggregates and uncemented quartzite blocks
From 2.60m to 3.90m	void
From 3.90 to 5.20m	strong Shale

The examination of the lithological cuts of the two drillings, revealed the presence of an embankment under paving formed of aggregates and quartz boulders, these latter prevailed over a distorted sandstone and very distorted that indicted by place a sandy dissolution. Furthermore, these drillings revealed concrete injected at different profundities which was probably used for clogging of the cavities and voids.

V. AUSCULTATION BY GEORADAR

The application of this technology is based on the scan, and the propagation of electromagnetic waves.

The GEORADAR allows the auscultation from the surface for recognition in this case of any ultimate underground cavities, voids, depressions, The tests radar were realized using two antennas with a frequency 1.5 GHz and 400 MHz (Fig. 2). The frequency 1.5GHz antenna permits to probe the soil on a profundity of about 60 cm, while the 400 MHz frequency antenna permitted to reach the profundities of about 5 m.

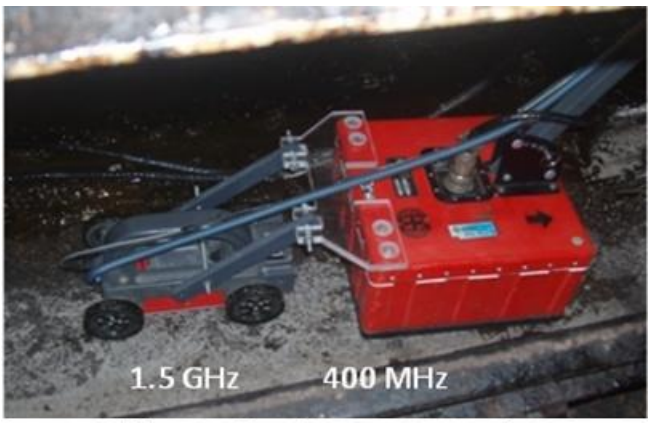

Figure 2 : Antennes radar

Picture 2: antennas Radar

The radar system is equipped with an odometer allowing the spatial location of measurements.

Comparison of radar data with data coring

Two lines of radar measurements, AR2 and AR 1, were performed at the level of the SC1 and SC2 holes respectively (Fig. 3). These methods were used to compare the results of the radar with informations provided by the two corings.

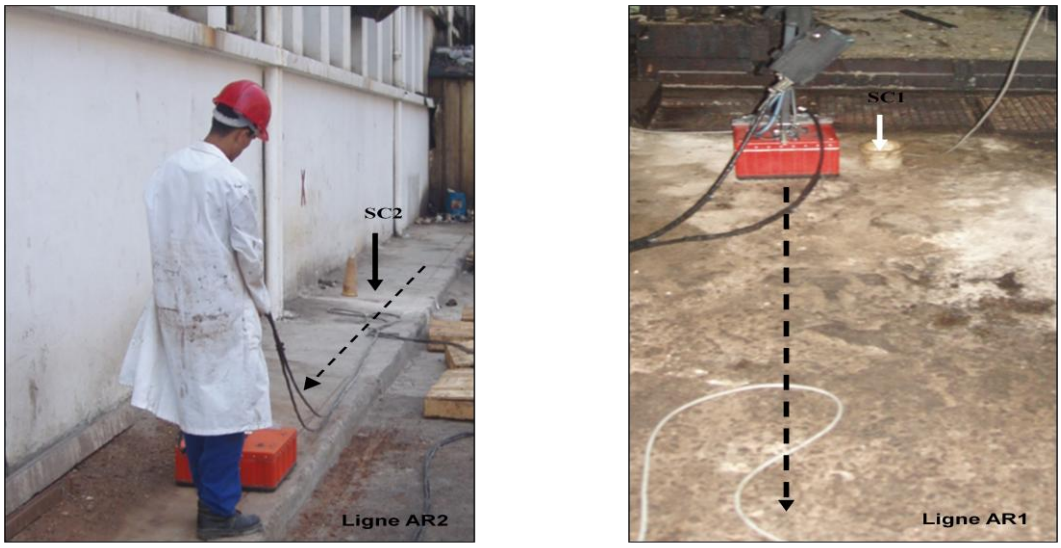

Figure 3 : Essai radar

Picture 3 : radar test

Measuring line AR2

a) Measurements at 1.5 GHz: The picture 4 gives the statement radar collected using the antenna of 1.5 GHz. The X-axis of this statement represents the distance (in meters) and the Y axis represents the profundity (in cm).

The SC2 drilling is located in chaining 6 m. On the existing radar data, the ground surface is about 10 cm on the Y axis The concrete slab is defined by the two yellow lines and its thickness is about 10 cm.

The radar profile shows the presence of voids under the concrete slab between 4.5 m and 9.5 m chaining as well as between the chaining 11m and 18m. By against, between 0 m and 4.5 m, the contact between the slab and the ground appears strong (continuity between the slab and the soil).

The SC2 drilling reveals the existence of Gravettes under the concrete slab. This is effectively reflected on the radar profile by the existence of voids in the slab as it is not a solid, compact and good adhesion with the slab at this point. Under the concrete slab (between 20 and 70 cm), the soil is not homogeneous because many diffraction hyperbolas are detected. These diffractions are simply caused by the interaction of the waves with the blocks of rocks (sandstone and loose gravel) in soil as indicated by the coring. Finally, an area of high attenuation is visible in the radar profile around 10 m. This attenuation may be caused by excessive moisture in the soil at this point, or by an absorbing soil.

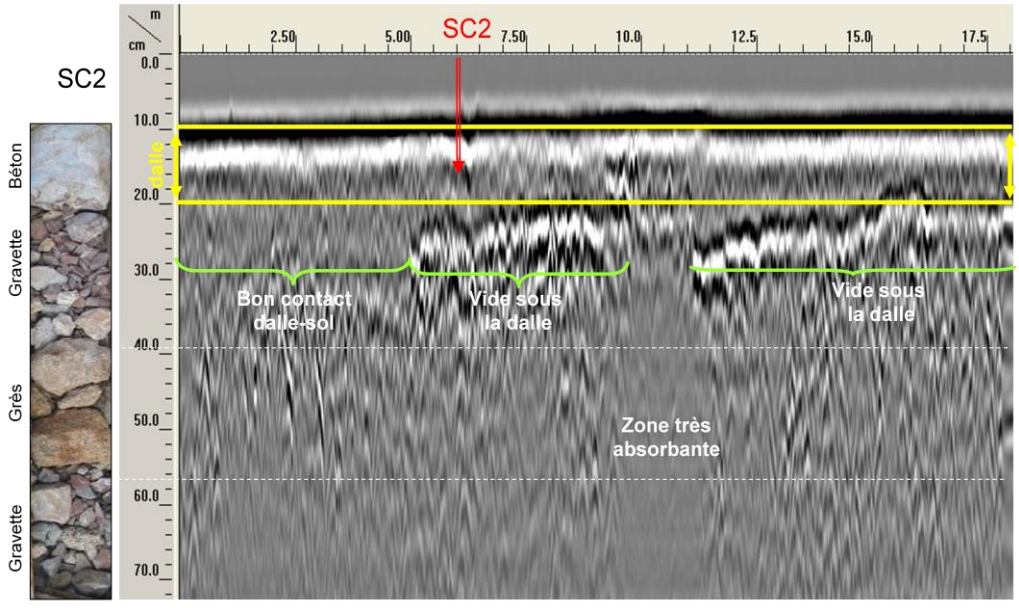

Figure 4 : Ligne AR2 / Mesures à 1.5 GHz

b) Measures at 400 MHz

The Picture 5 gives the radar drilling using the antenna of 400 MHz. The X-axis of this statement is the distance (in meters) and the Y axis represents the profundity (in cm).

The radar profile doesn't identify the border between the limestone and the shale as the electromagnetic contrasts between these rocks don't appear to be significant. Other borders between the sandstone and the sand (75 cm) and between the sand and the limestone (1.91 m) are also obvious as regarding the profile. Their detection isn't the primary purpose of this work.

The radar profile, however, shows the presence of the cavity which occupies the space between 3.11 m and 3.80 m deep. This cavity appears on the profile as a reverberation. The top of the void coincides with the top of the reverberation. On the right side, at 17.5 m, the radar profile also highlights the presence of hyperbole which, in the absence of underground pipe there, is probably associated with an underground cavity.

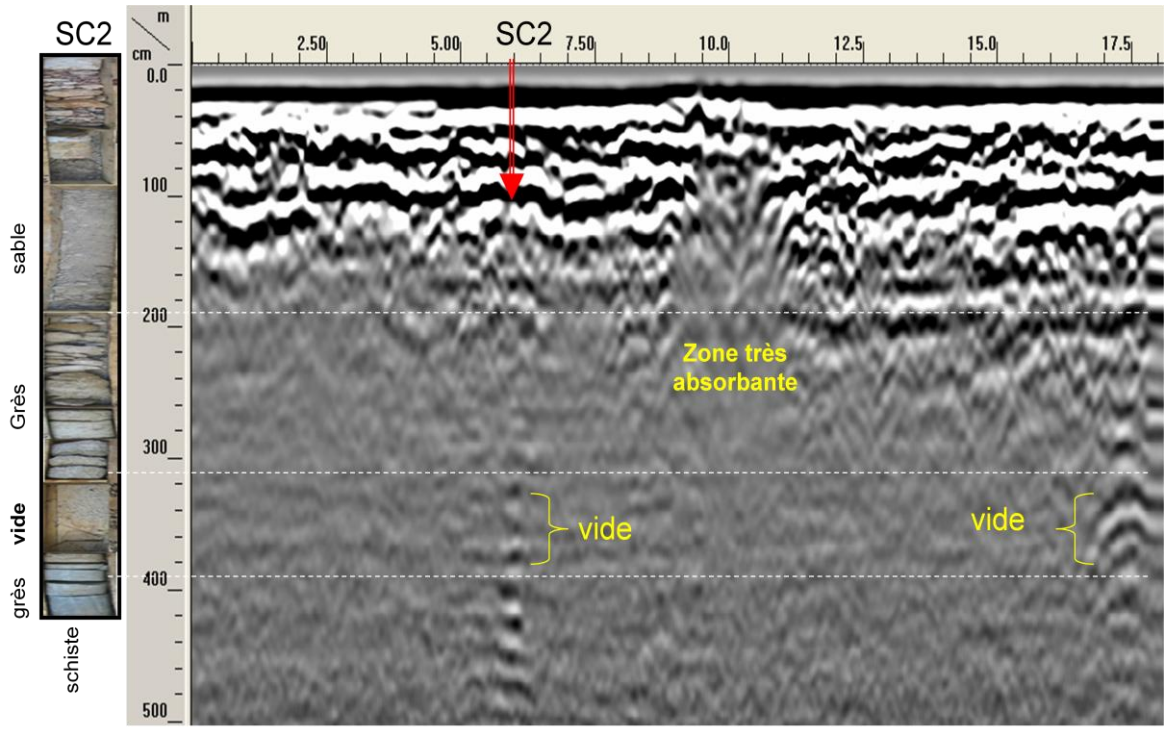

Figure 5 : Ligne AR-2 / Mesures à 400 MHz

Picture 5: AR-2 Line/Measurements at 400 MHz

- **Line of measurement AR1**

The SC1 drilling is situated at the beginning of the measuring line AR1 (Fig. 3). Here, the Comparison Radar -drilling is less interesting than in the case of the line AR2 or the SC2 drilling is in the middle of that line.

a) Measurements at 1.5 GHz

Picture 6 gives the statement radar collected using the 1.5 GHz antenna. The X-axis of this statement is the distance (in meters) and the Y axis represents the profundity (in cm).

The slab contains only a row frame that the profundity is lower on the right side of the profile. The slab-floor contact does not seem to be solid. This is confirmed by the core that indicates the presence of sand under the slab. The soil under the slab (20-60 cm) appears to be homogeneous and doesn't indicate the presence of large boulders as in the case of SC1 drilling.

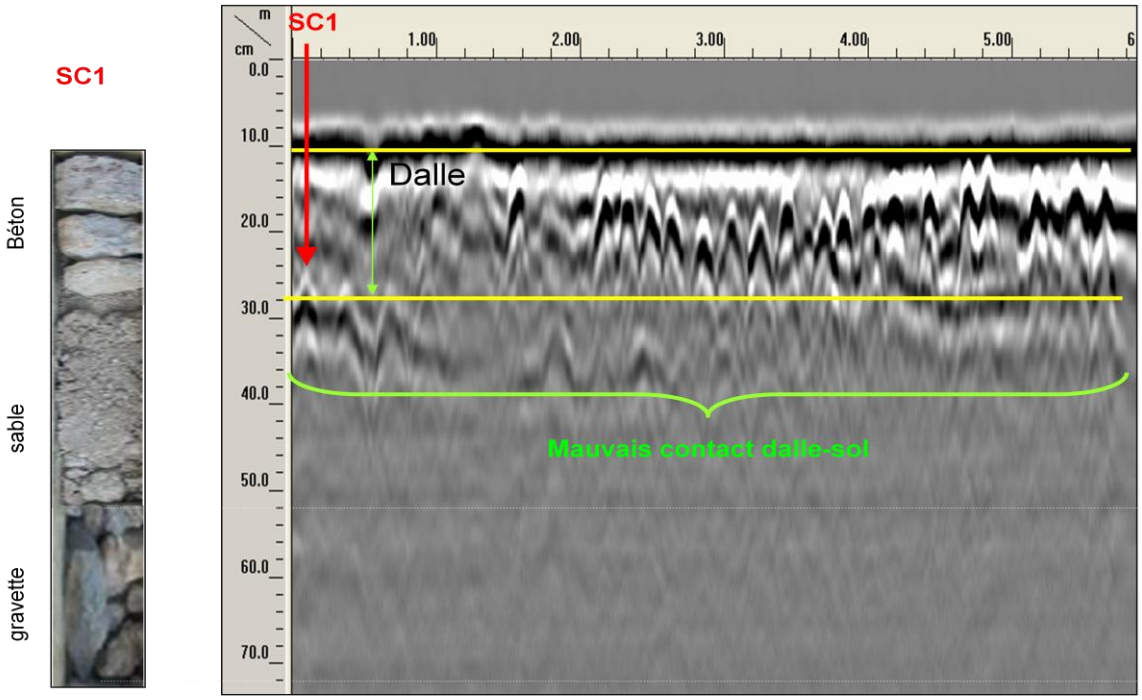

Figure 6: Ligne AR1 / Mesures à 1.5 GHz

Picture 6: Line AR1 / Measurements at 1.5 GHz

b) Measures to 400 MHz: The radar profile (Picture.7) shows intense parallel horizontal reflections. These reflections are most likely attributed to the fissure (or dissolutions in horizontal planes) of the rock mass.
The SC1 drilling doesn't reveal the presence of voids but indicates that the factor RQD (Rock Quality Designation) is very low. The radar profile on the level of this drilling shows borders (indicated in yellow) which are associated with less severe ruptures planes than those observed on the side of the profile (x = 4m).

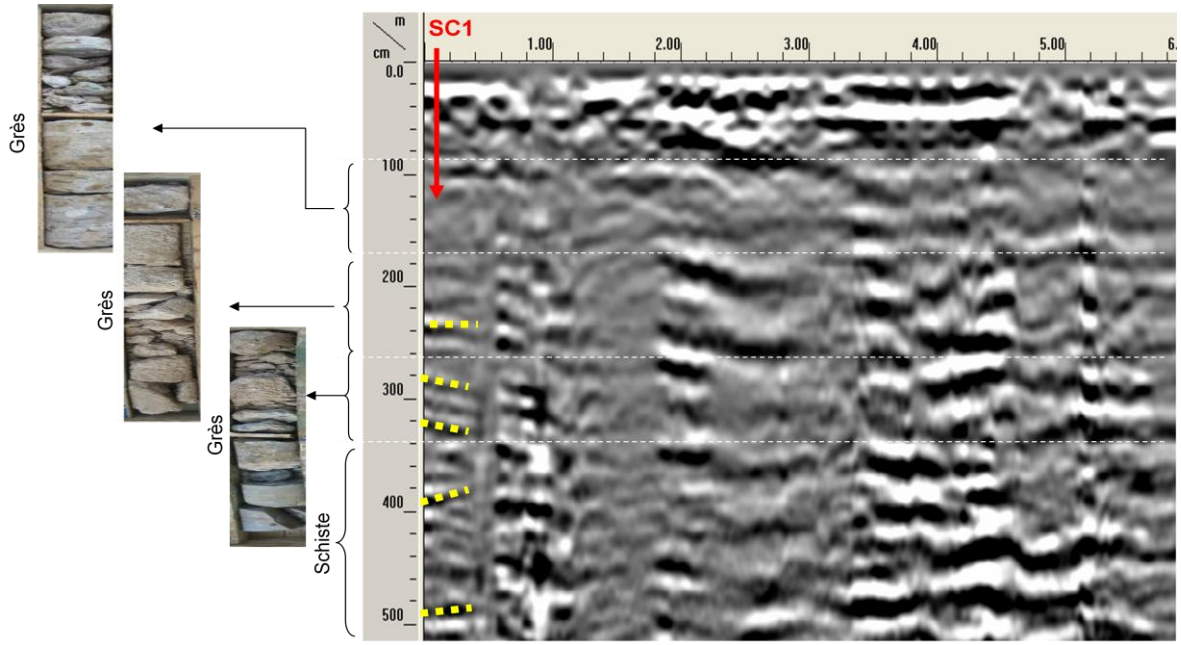

Figure 7 : Ligne AR-1 / Mesures à 400 MHz

Picture 7: Line AR-1 / Measurements at 400 MHz

VI. CONCLUSIONS

The discovery of the cavities in the soil by the GPR technique is a prevailing and important test for the buildings and the infrastructure based or may be based on soils with voids.

The GPR technique joined with the usual destructive drillings is consistent and converges with the same conclusion, After several tests, it appears that the audit by lower frequency antennas (400 MHz) is possible for the profundity of investigation of about 500 cm antennas with frequency 1.5 GHz profundity of investigation remains low about 50 cm. The advantage of the technique of radar is that it allows a full scan of the subsoil of the surfaces to control.