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Ground Penetration Radar to investigate Soil Beneath Foundation for a Constructing in Karbala City

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Abstract. In civil engineering, ground penetrating radar, or GPR, is an intelligent, non-intrusive and safe sensing method with a variety of conventional and cutting-edge uses. The aim of this investigation is to identify buried corpses, walls, and geological characteristics such as collapse structures, weak zones, joints, cracks, voids, and cavities in the underlying sediments in the foundation of the hotel structure in the middle of the Karbala District, this study will use a GPR survey. Using two antennas operating at 160 and 450 MHz, fieldwork including 46 profiles were performed at the location, which measured 15 by 15 meters and 225 square meters. The Results indicate that there are several subsurface characteristics in the survey region, including creep, collapse, fill materials, and weakness, which point to a weak zone that extends to level of six meters. These zones spreading over the area of a hotel construction and begin beneath the foundation and go down to a depth of around six meters. which Reflected on the building, causing the erosion of the soil and the cause of this collapse. Consequently, the areas of weakness were concentrated on the outer walls of the structure, especially those in which cracks spread in their walls.

Keywords. GPR, Antenna, Collapse, Foundation, Radagram

INTRODUCTION

The use of geophysical techniques to examine subsurface features and materials that may have engineering implications is known as engineering geophysics. The geophysical technique known as Ground Penetrating Radar (GPR) was initially created for high resolution subsurface imaging. It might identify a discontinuity in the normal stratigraphy or soil profile, or it might identify the disturbed soil of the grave shaft [1]. The primary uses include measuring the moisture content of natural soils and artificial materials, surveying road pavements, bridge decks, tunnels, and underground utilities and items. Furthermore, noteworthy instances of the application of GPR in railway, geotechnical, and structural engineering must be highlighted [2]. Particularly in engineering, environmental, and archeological applications, GPR has gained a great deal of popularity for understanding and characterizing subterranean geological features [3]. The main advantages of GPR, which underpin its success in the field of civil engineering, are its non-intrusive and non-destructive surveys, much reduced costs when compared to older technologies immediate information collecting, dependability, Regarding the metrics' representativeness [4]. Electromagnetic waves with radio frequencies between 30 and 3000 MHz are used in the ground penetrating radar (GPR) method of subsurface exploration. The choice of antenna frequency for GPR surveys is contingent upon the

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particular use case; geological applications tend to favor lower frequencies, whereas engineering applications favor higher frequencies [5]. [6] mapping subsurface features of multistory building foundation site in Karbala governorate by GPR. Because GPR offers a quick, affordable, and non-destructive way to examine the shallow subsurface, it is crucial for managing Earth's finite resources and supplying the demands of an expanding population in the twenty-first century.

Aim of Study

The aim of this study is to identify buried corpses, walls, and geological characteristics such as collapse structures, weak zones, joints, cracks, voids, and cavities in the underlying sediments in the foundation of the hotel structure in the middle of the Karbala District.

Location of Study Area

The investigate site is approximately 100 kilometers north of Baghdad in the middle of the Holy Karbala District, Karbala (central southern region of Iraq), between latitudes (32635011"N) and longitudes (4414703 "E). Fig1.

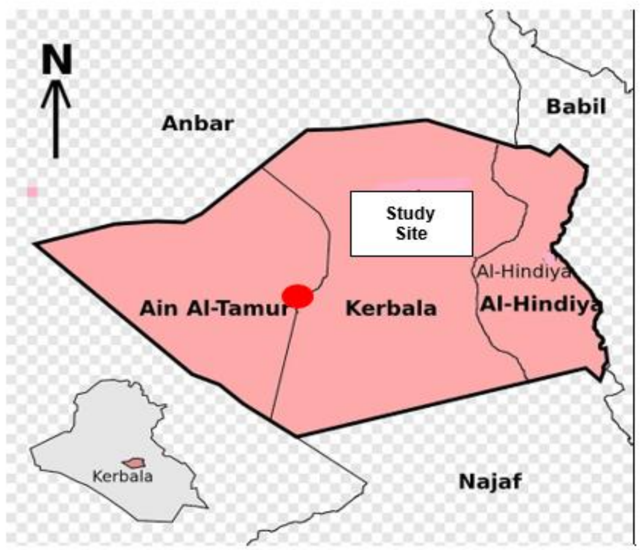


Figure 1. Map of study area

Geological and Tectonic Setting

The survey (Karbala Plain) was conducted on a level area with unconsolidated soil that is made up of gravel, silty, sandy, and clayey soil. According to [7], the location is tectonically within the Unstable Shelf, which is a portion of the Euphrates sub-zone. It is distinguished by the presence of NW-SE structures and faults, such as the Abu-Jir Fault, which runs parallel to the Euphrates River and serves as the tectonic boundary between the Unstable and Stable Shelves. The Abu Jir Fault Zone crosses the area being studied region and, as demonstrated by [8] in the surrounding areas, has a significant impact on the topography of the region, notably the arrangement of the ridges and depressions. According to [9], the Southern Desert of Iraq is located in the stable region of the Arabian Platform, where exposed Cenozoic rock units slope gently east and southeast into the unstable region. The exposed formations in the examined region are the following, in order of age: Euphrates, Fatha, Nfayil, Injana, Zahra, and Dibdibba. The deposits from the

Quaternary period envelop the research area. The Fatha Formation, which includes uncommon siltstone and sandstone together with marl, claystone, limestone, and gypsum, is a representation of the exposed Tertiary rocks. The Dibdibba Formation is mostly made up of sand, gravel, and gravelly sandstone with clay lenses made of compressed clay balls filled with gypsum and sand as a cementing agent. The Injana Formation is primarily made up of sandstone, siltstone, and claystone. The Tertiary formations underneath are covered by Quaternary sediments, which are mostly composed of Pleistocene and Holocene sediments from river terraces, gypcrete, flood plain sediments, and aeolian sediments. Nearly all of the soil in the examined region is composed of these sediments, Loose sediments can be exposed to liqufication with time [10]. Figure 2 displays the Holy Karbala region's geological map.

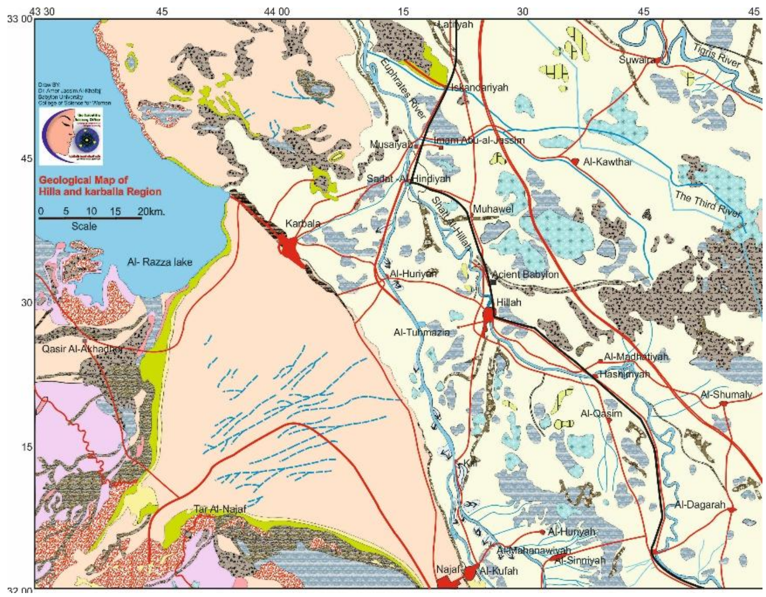


Figure 2. Geological map of Holy Karbala region

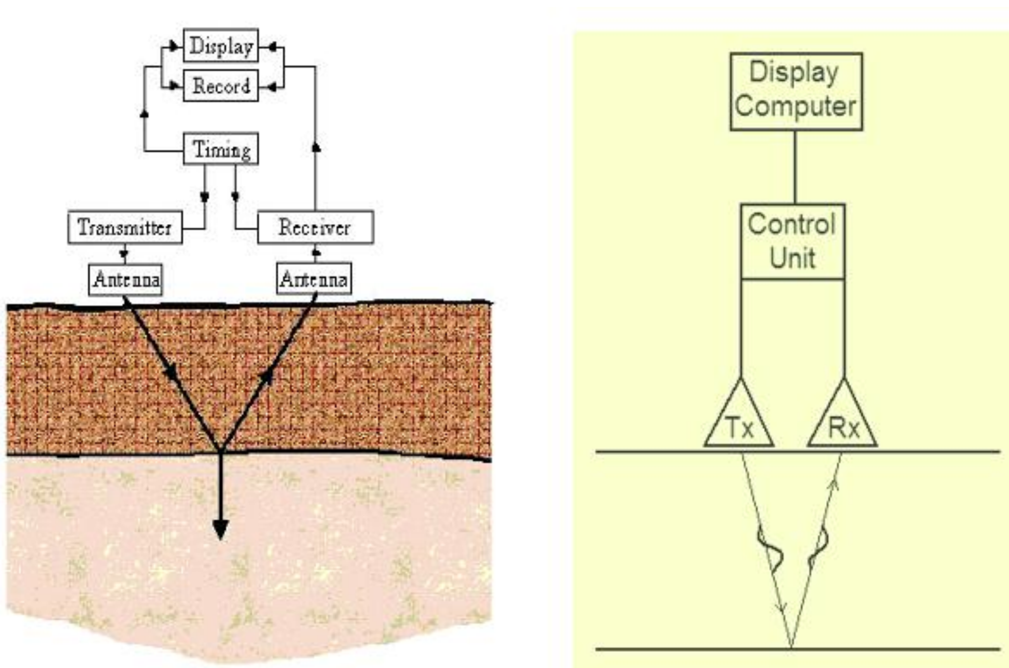
MATERIAL AND METHODOLOGY

In theory, sonar techniques and the GPR technology are comparable. Through the use of an antenna, the transmitter of radar emits a brief electromagnetic pulse with a high frequency (25–1000 MHz) radiation into the ground. Changes in the electrical impedance of the earth produce reflections, which the same antenna or a different one connected to a receiving unit detects at the ground surface. Changes in the ground's relative permittivity or dielectric constant are primarily responsible for changes in electrical impedance. For a typical incident signal, the reflection coefficient is:

$$R = \frac{\sqrt{E1} - \sqrt{E2}}{\sqrt{E1} + \sqrt{E2}} \quad (1)$$

where E1 indicates the medium 1 dielectric constant and E2 indicates the medium 2 dielectric constant.

The determination of radio wire recurrence in ground-entering radar (GPR) studies assumes a basic part in deciding profundity entrance and goal of subsurface elements. Lower frequencies offer further entrance, while higher frequencies give improved goal to imaging shallow highlights. Higher recurrence radar yields higher goal because of more limited frequencies, zeroing in on more modest regions and settling better subtleties [11]. Higher frequencies likewise lead to expanded lessening and diminished entrance profundity. Conductive mediums disperse more energy with more limited frequencies, influencing entrance profundity. In site examinations, frequencies between 50-200 MHz are suggested for more profound focuses, while frequencies over 200 MHz are appropriate for shallower targets. Goal improves with higher frequencies and dielectric values, affecting the capacity to recognize interfaces in both flat and vertical headings. [12]. Ground-entering radar (GPR) works on the standard of utilizing electromagnetic waves rather than acoustic waves like seismic strategies, furnishing higher goal maps however with less profundity infiltration. GPR instruments recognize focuses with differentiating electrical impedance to the encompassing media, making them reasonable for finding metallic and non-metallic focuses up to around 30 meters down. The GPR framework incorporates a transmitter (Tx) that discharges electromagnetic energy into the ground, a beneficiary (Rx) that proficiently catches reflected signals, and a control unit that oversees signal boundaries, timing, intensification, separating, and digitization [13]. The framework likewise includes a PC controlling the unit, putting away information, and imagining results. Ordinarily, the transmitter, enhancer, and digitizer gadgets are incorporated with the receiving wires to limit commotion from associating links.



(a) (b)

Figure 3. GPR system's general scheme. the electromagnetic (EM) signal that is generated by the transmitter antenna (Tx), The reception antenna (Rx) receives(a), amplified, digitized, and stored (b).

A commercial GPR equipment, the MALA GX equipment TM from MALA Geoscience [14], was utilized in this investigation. It consists of a radar control device powered by a 12-volt battery. The Control Unit has a 32-bit CPU that is connected to an antenna on one side and a storage display device on the other. The control unit has a specific monitor installed on it. A computer for data collecting, preliminary processing, and filtering is located on the side of this display. The entire equipment is transported on a specialized cart that has a distance meter installed. The primary GPR equipment, the MAL̄ GX System, is shown in Figure 3. Using a variety of antenna frequencies with a single control unit is one benefit of the MALA GPR system. It is possible to connect both the shielded and unshielded antennas with frequencies between 25 MHZ and 2.7 GHz directly to the same control unit. In the field, switching antennas may be accomplished very simply. Antennas at 160 and 450 MHz are employed in this investigation. Plate1.

Plate 1. GPR main equipment MALÅ GX System

Field Work

Within the hotel building, which has dimensions of 15 by 15 meters (225 square meters), field work with 46 profiles has been examined. The profiles that are longitudinal. The field survey design serves as a foundation for organizing surveys, determining the optimal needs for the survey, and determining the most appropriate operational specifications for the antenna-equipped GPR apparatus. Two kinds of antennas —GX 160&450 MHz—with two stages at a 23-meter survey length were employed along these profiles. The position map of the site's GPR survey lines is displayed in Fig.4.

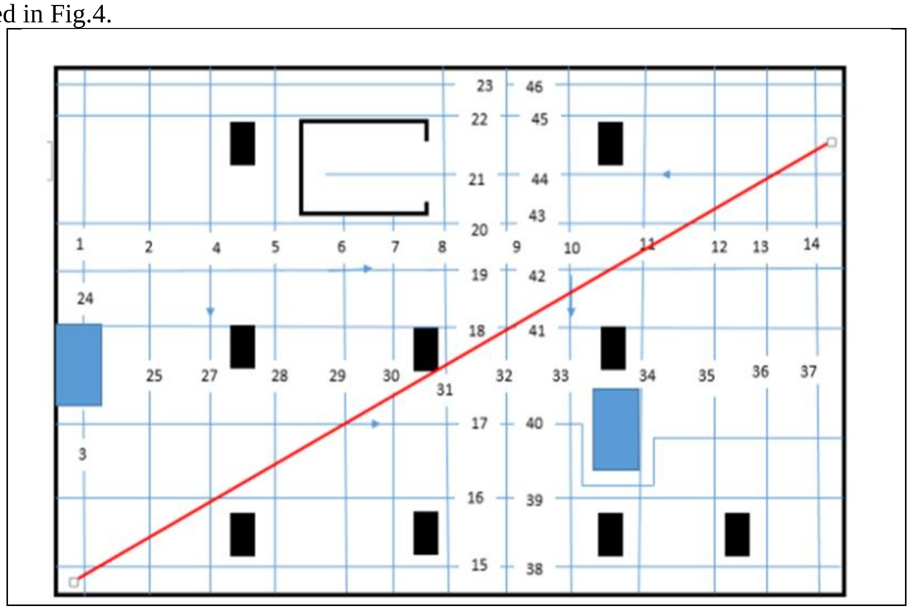


Figure 4. Location map with GPR survey lines Hotel Building Project

On the laptop computer that was in charge of the measurement, survey data were entered. During measurement, real-time filtering is possible due to ground visibility. Reflector Point Horizontal Reflector Planar reflectors will retain their normal shape whereas point reflectors will register as hyperbolas due to spherical dispersion. Depending on the antenna frequency used, the findings' precision spans 0.01 to 1.0 meters in both the horizontal and vertical directions. greater resolution is associated with reduced penetration when the antenna frequency is greater, inversely .

Ground Penetration Radar (GPR) Data Processing

RadExplorerTM (version 1.2) was the software used to process the GPR data. In order to maximize the signal strength and profile quality, 48 GPR data tests, or profiles, were fed into RadExplorer and subjected to a standard collection of operations. Each radar profile underwent a different set of processing operations, including automated gain control, median filtering, band-pass (1- and 2-D) filters, and background removal. The purpose of the band-pass filtering was to get rid of high-frequency elements. Figure 5 summarizes the typical GPR data processing procedure. Highlights four key areas of data processing, which include basic processing, complex processing, data manipulation, and processing for display and interpretation. These sections are indicated in purple. Before the data is finally finished at the visualization stage, processing is typically an iterative process in which it goes through many loops. Large datasets may be subjected to cluster processing with restricted interactive control after preliminary testing on chosen information samples has been completed. Without the requirement for extra subsurface details, including data rectification, filtering, and trace editing, the fundamental processing procedures are frequently implemented to the unprocessed data (often automatically) and present little operator prejudice in the dataproprietary format for saving processed files.

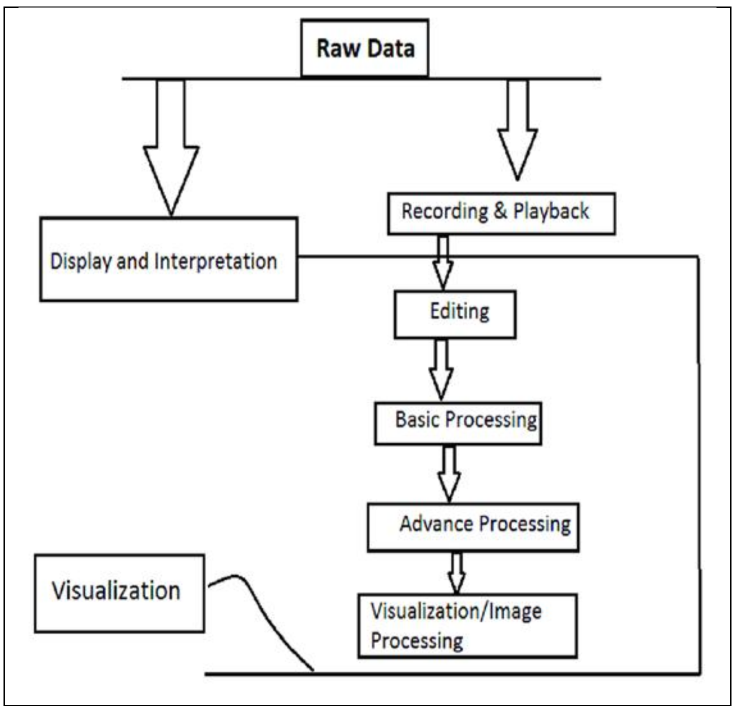


Figure 5. Overview of GPR data processing flow

RESULTS AND DISCUSSION

RadExplorer, a proprietary program, was used to process 46 Radar grams (Figure 6 through). GPR data interpretation is a difficult process that may be comparatively clear-cut at times and subjective at others. The types of antennas determine the penetration depth. application of processing on the Radargram data, findings showed the existence of an abnormal feature throughout the survey region. Because of the shorter contact and increased contrast between the soil layers that are compacted and loose, the initial interface becomes considerably more visible. The soil under the earth's natural surface is made up of weak zones, walls, collapses, fill material, and old building, from a depth of 1 meter to a depth of 6 meters and during this depth there are areas where soil precipitation occurred as a result of the natural burial work and in which the process of soil compaction did not occur. The spread of weak zones, represented by a possible basement for an old building, reaching a depth of 6 meters. Strong soil appears with a depth of 6 meters. The water table non recognized. Many ancient residual walls are visible extending along profiles at different depths, as shown by the red rectangle lines. Human-made anomalies are easily recognized because they include segmented parts of high amplitude (high contrast) floor characteristics and form geometric, architectural patterns in plain view, even though contrasts can also be produced by variances in subsurface conditions caused by geological and cultural differences. The disappearance of the set of black and white replies indicates that the change in the topsoil and subsoil boundaries must be the source of this reaction. The layer spreads out at various depths. Additionally, discrete subsurface objects cause unique hyperbolic reflections (arcs) to be visible. Comparable, these exaggerated reflections are probably the remnants of the former Hotel Building's foundation or the original arcing arcs. Human graves can be found using the GPR test in a number of ways. It might identify changes in the natural stratigraphy or soil profile, as well as the dispersion of the soil. The paths Figure 6 (a, b, c, d, e, f, g) represent fill material, collapse, weak zone and creep.

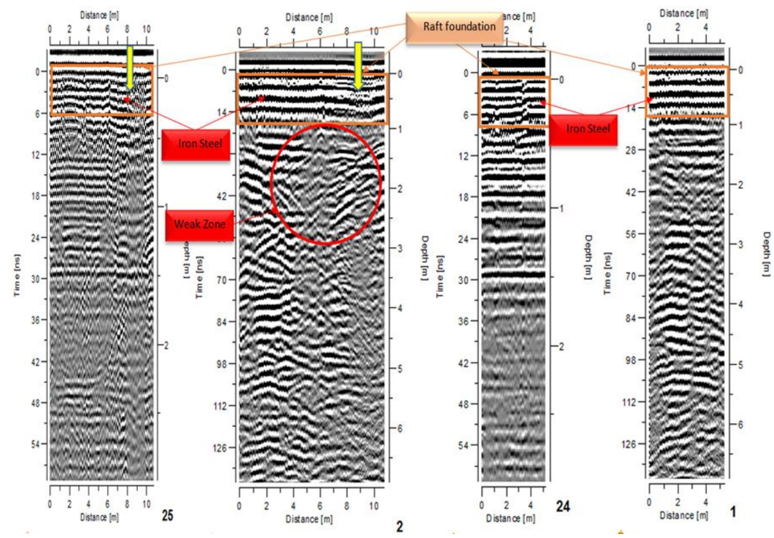


FIGURE 6. a .The Radargram of profiles (1,2,24 and 26) represents weak zone and raft foundation with antenna 450 and 160 MHz.

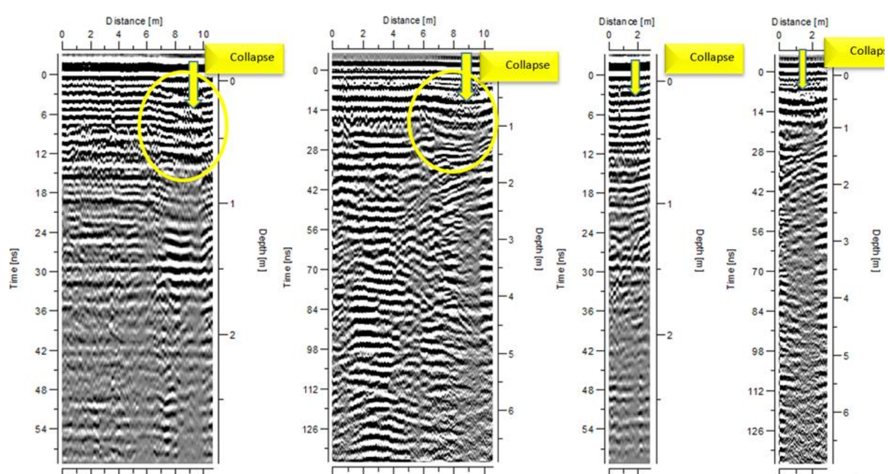


FIGURE 6. b.The Radargram of profiles (3, 4, 26and 27) represents collapse, with antenna 450 and 160 MHz.

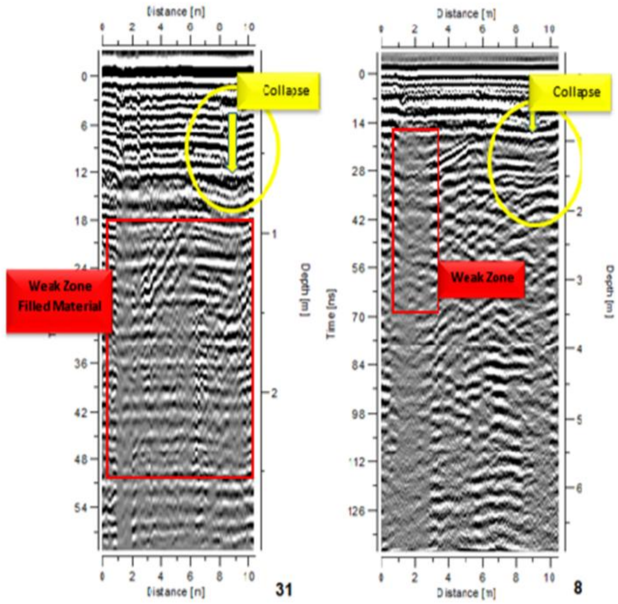


FIGURE 6.c.The Radargram of profiles (8 and 31) represents collapse, fill material, and weak zone with antenna 450 and 160 MHz.

CONCLUSIONS

The following results are drawn from using the GPR technology for shallow engineering studies at the foundation site of the Hotel Building:

1- The thickness of the mat foundation was approximately 75 cm shown through georadiographic sections.

2 - The georadar survey identified soil encroachment, areas of weakness, fill materials, collapse, and creep, indicating a weak layer extending to a depth of 6 meters, offering valuable insights into subsurface conditions and potential geotechnical challenges within this depth range.

3- The spread of weak zones, collapses and creep of soft particles of soil in the front facade, on both sides and in the interior, and the building rushes forward. It is expected that there will be irregular corridors to drain water to the area, as well as the exposure of the foundation soil to a process of drawing water from neighboring buildings and the presence of potential leaching in the water lines Existing in the building and the neighboring buildings, the presence of leaching of the liquefied water and sewage networks and as a result of the process of dragging and unloading the fine soil particles under the foundation, the cause of this damage to the soil and that the soil of the site was affected by it, as well as the possibility that the soil of the foundation may not be well drained. The weak areas begin under the foundation and extend down to a depth of around six meters, which Reflected on the building, causing the erosion of the soil and the cause of this collapse. Consequently, the areas of weakness were concentrated on the outer walls of the structure, especially those in which cracks spread in their walls.

4- Concentration of soil encroachment trends and weakness in the direction of manholes. It is expected that there will be exudations in the sewage network for sanitation, and this is evidenced by the subsidence of soil in these locations through survey paths.

5- The strong soil layers appears with a depth of 6 meters.

RECOMMENDATION

The ground penetrating radar (GPR) study results indicate that in order to treat these locations and enhance the engineering qualities of the soil beneath the foundation, it is necessary to treat these areas by injecting the soil with cementitious material to a depth of 6 m. we recommend the following: -

1- Experimental drilling with a diameter of 3.0 inches and a perforated iron pipe with a diameter of 2 inches and then a lock made up to a depth of 6 meters from inside the building vertically, the distance between one hole and another is 2 meters. The pipe is punctured from under the mat, and 25 cm from the top remains outside the pipe. Then, the soil is injected with cement with additives to improve the properties of the soil and apply a pressure of 10-15 bar. The injection starts of the building until all the test excavations are completed, then from the inside in Fig 7.
2- taking this The presence of gypsum in the soil makes soil as a basis for engineering facilities is completely undesirable, as the dissolution of gypsum and its transfer by water into the soil exposes the installations to decline and failure. Therefore, utmost precautions must be taken to keep water away from the soil near the origin. It is done by the following means as follows: -

A- Connecting the building's water and sewage network above ground level in a visible way to control any leakage or other expected problems.
B- Reducing the washing of garages and walkways as much as possible

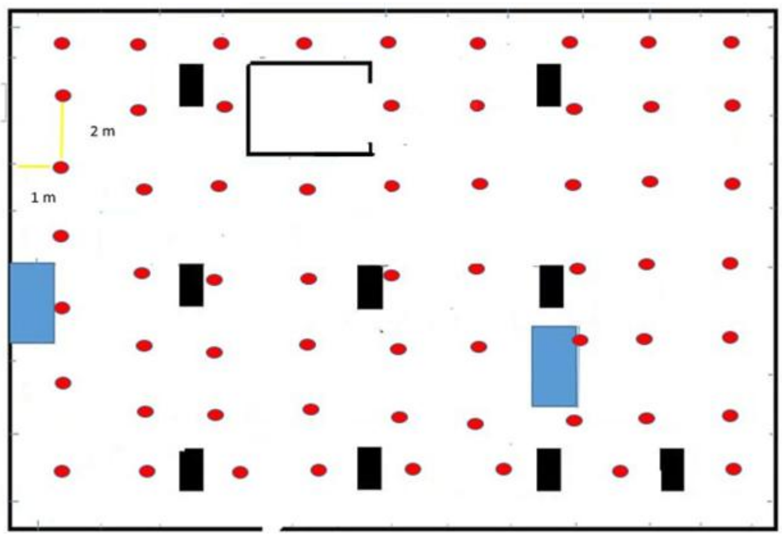


Figure7. Distribution diagram of test pits for injection on site
The diameter of the hole is 3 inches - Iron pipes with a diameter of 2 inches - The depth of the hole is 6 meters, the distance of the wells from the wall is 1 meter - the distance between one well and another is 2 meters.

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