# Performance of Ground Penetrating RADAR Technique in Assessment of Heritage Structures

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**Abstract -** *Heritage structures are important for its culture and pride. They are historic evidences. There is a need to inspect and maintain them. Inspecting of structure by taking the samples of the structure may disturb the view and strength of the structure and more over the complete detail of the structure may not be found by taking few samples. Importance of non-destructive testing has been developing to solve this problem. There are many non-destructive testing methods evolved in last few decades. The usage of those methods depends on the accessibility and accuracy of those methods. To reduce the error and get more data RADAR concept is being developed. The GPR (Ground Penetrating Radar) used here gives the signal images only. To study and compare, data of signals of different possible errors are required as reference. An acoustic wall (similar to most of heritage structures in India) is build inducing all the possible defects. The data from GPR shall be considered as reference for such experiments done on heritage structures. The signal processing is done using MATLAB, RADAN, and SIR software.*

***Key Words*: Acoustic stones, heritage buildings, GPR (of frequencies 2.6GHz, 1.6GHz, 900MHz, 400MHz), RADAN-7 and MATLAB.**

## 1. INTRODUCTION

Non-destructive testing on heritage structure is important to transfer the knowledge, culture and techniques used in their construction to the next generation. GPR (ground penetrating radar) is a type of RADAR, which uses radio waves as the signals [1]. Using this we can find the details of structures other than the surface features. Non-destructive testing on heritage structure is important to transfer the knowledge, culture and techniques used in their construction to the next generation. GPR (ground penetrating radar) is a type of RADAR, which uses radio waves as the signals. Using this we can find the details of structures other than the surface features.

### 1.1 Heritage structures

Heritage structures are important for culture, historical representation, art and aesthetics. Heritage structures include ancient stone masonry buildings and buildings made with mud, lime mortar etc. Some of them represent history, art, landmark and few are for diversity. Depending on the purpose, heritage structures are classified into two types. They are Tangential heritage structures and in-tangential heritage structures. Tangential structures represent buildings and historic places, monuments and In-tangential structures represent traditional or living expressions and style, social practice, oral tradition, culture and festival.

According to UNESCO world heritage center, India is the 6$^{th}$ largest country in terms of number of heritage structures. Many structures in India, which are demolished, and few were not maintained properly also falls under the category of heritage structure.

Currently in India, there are 38 heritage structures recognized by UNESCO. In this, 30 are cultural and 7 are natural. One is of both cultural and natural. There are many other heritage structures in India maintained by Archaeological Survey of India (ASI) along with central and state government.Currently there are 3684 monuments recognized by archaeological survey of India. These are maintained by both ASI and state governments.

### 1.2 Ground Penetrating RADAR

GPR is developed to find the materials and water source in the Earth. In GPR, the micro waves are used. The depth of the data obtained depends on frequency of the RADAR. GPR has three major components:-

i. Control unit
ii. Antenna
iii. Survey wheel
iv.

Control unit controls the scanning process. Trigger is provided in control unit to start and stop the scanning. Antenna receives the data reflected from the objects. Survey wheel

## 2. EXPERIMENTAL STUDY

### 2.1 Methodology

To understand possible defects, Visual inspection of heritage building is more important. Few heritage structures in Chennai, Tamil Nadu are visited. Major defects in heritage structures are voids. To study the materials filled in the voids, a stone masonry wall with voids is constructed similar to heritage structure. The voids are filled with coarse aggregate and fine aggregate so that the hyperbola of the GPR is easily understood. Here the stones are not joined by any mortar to study the cracks. In GPR the micro waves are used

### 2.2 Materials

Acoustic stones, fine aggregate and coarse aggregate were used for the construction of wall. The stones of smooth surface are used so that the surface of the wall is smooth and no run time error will occur.

The stones used here are very strong and similar to the stones of heritage structures visited. Two voids are created in the wall. One filled with coarse aggregate and other filled with fine aggregate. The size of both voids is 20cms. Here the bigger dimension voids are created to check the percentage of error using GPR. The dielectric constant of the stones and aggregate is different. The micro waves are reflected only if there is difference in dielectric constant. As the dielectric constants of two different materials are not same, the hyperbola is obtained in the graph. Back wall reflection will also be obtained as the dielectric constant of wall and air is different.


**Fig-a**

**Fig-b**

**Fig-1:** Acoustic wall in south and top directions

Here the GPR is run across the void on the south side of the wall. The antenna of frequency 1.6GHz is used for the scanning. High frequency gives more detail data.

## 3. RESULTS AND DISCUSSIONS

Before constructing the wall, the strength of the stones is tested. Three random stones are taken to test using ultrasonic pulse velocity and compressive testing machine. The results of the tests are as follows.

Table -1: **Compressive Strength of stone**

| S. No | Specimen | Compressive strength ($N/mm^2$) |
|---|---|---|
| 1 | S1 | 99.80 |
| 2 | S2 | 101.20 |
| 3 | S3 | 128.00 |
| Average compressive strength ($N/mm^2$) | | 109.70 |

Table -2: **Ultrasonic pulse velocity of Stone**

| S. No | Specimen | Pulse velocity (km/s) |
|---|---|---|
| 1 | S1 | 6.30 |
| 2 | S2 | 6.10 |
| 3 | S3 | 6.30 |
| Average Ultrasonic pulse velocity of Stone(Km/sec) | | 6.20 |

From the table-1 and table-2, it is found that stones are very strong. The physical characteristics of stones are similar to the heritage building. So these stones can be used for construction of specimen.

The wall is tested using GPR. As the sizes of voids are predefined the results from GPR can easily compared and error percentage is found. Here portable GPR is used for scanning. The scanned results of GPR are as follows.

The frequency of the antenna used is 1600GHz... The depth of the data is restricted to 40cms so that the back wall reflection is avoided and more clear data is obtained.

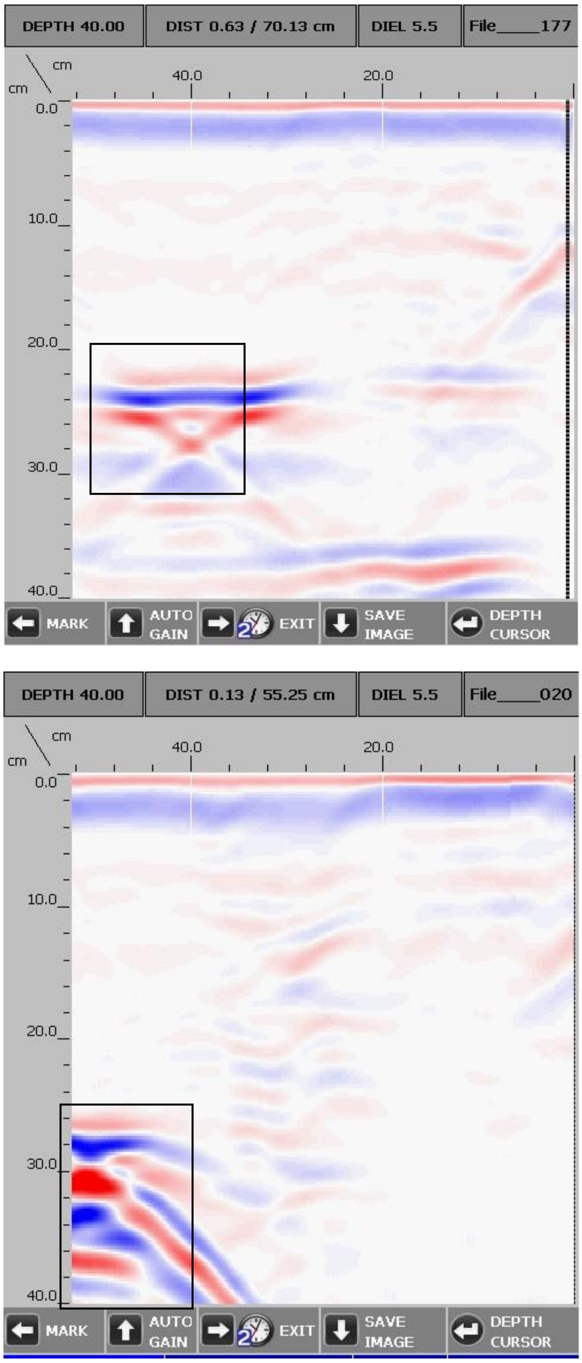


**Fig-2:** scanned data (radargram) of voids in perpendicular dimension.

The highlited portions in the radargrams are the reflections of voids. The position of occurance of hyperbola gives the data of the change in medium. The width of hyperbola gives the width of the changed medium. The depth of hyperbola gives the location of the changed medium. To find the character of the medium a proper reference is required. Hyperbola will be different for each medium.

In the radargram-2, initial lines at 0.0cm are because of no proper contact with the surface. This is an error and this should be removed in the depth values. In the radargram, void is shown at a depth of 26cms and the surface error is 3cms. So the exact depth of the wall from GPR is 23cms and actual depth is 9 inches i.e., 23cms. In radargram-1, the depth of void is 23cms and error is around 3cms. So the depth is 20cms (23-3). The actual depth of void is 8inches i.e., 20cms. By this, we can say that GPR can find the exact depth of the wall. The height of the void is 20cm. and the distance of hyperbola is approximately 20.5 cm. The location and depth of hyperbola and the void is exactly same. The only error here is in the height of the void.

The percentage error in the GPR = $\frac{(20.5-20)}{20}$ x 100 = 2.5%

The error using the GPR is very less. The error is less because of using high gain values.

Here to analyse the GPR Radargram SIR-2000 and MATLAB are used. The width of the hyperbola is found by increasing the gain and normalizing the radargram.

## 4. CONCLUSSIONS

Based on the experimental study, the following conclusions can be drawn

- By using GPR, dfects inside the structures can be easily found. The dimensions of the defects can also be found easily
- A skilled person can even find out the type of defect. For this a proper study and reference is required
- No error is found in finding the depth of the defect.
- Very minimal error is found in finding the dimensions of the defects.
- The hyperbola width can be properly understood by changing the gain but by changing the gain value radargram may not be understood easily.
- Using softwares like RADAN-7, SIR-2000, MATLAB the error can be further reduced.

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