Effectiveness of GPR on Structural Assessment: Hints for the Potential User

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Summary

In the current study, the results from various in-situ calibrations in several existing concrete structures are being presented and discussed, leading to useful conclusions and comments about the correct application and the effectiveness of Ground Penetrating Radar (GPR) technique on structural integrity assessment. Specifically, the effect of two different antenna frequencies on scan results is being examined. Two types of scan modes, distance and time, have been applied and are being evaluated. Other parameters, like antenna contact to the concrete surface, scan velocity, antenna resolution and scan repeatability, are also being investigated. The application of grid versus linear scan patterns is being discussed. Useful observations and hints are reported for the potential users of GPR. It has been found that high quality results can be obtained by using a suitable antenna frequency, the use of carefully selected data acquisition settings and a steady scan application, in terms of the antenna to surface contact and scan velocity. Additionally, the high level of repeatability allows the monitoring of infrastructure in recursive intervals, which may prevent the expansion of local intrinsic defects.

Keywords: structural assessment; non destructive testing; ground penetrating radar; antenna frequency; surface contact; scan velocity; resolution; repeatability.

1. Importance of Structural Assessment and GPR

Structural assessment of existing infrastructure is considered to be important due to the significant lack of expertise in the former decades of the past century, which is characterized by poor construction methods and quality assurance level. In addition, structural assessment is critical due to the unavailability, the obscurity or the imprecise application of structural design drawings, as well as due to the imposed or accidental incompatibility of structural design drawings with existing condition. Finally, another significant reason for the requirement of structural assessment is the historical path, in terms of environmental or special exposure (climate exposure, such as chloride ingress, carbonation, high/ low temperatures, earthquake, fire etc.), as well as possible rehabilitations or repairs at different stages and through different motives.

Many different Destructive or Non Destructive Testing (NDT) methods have been proposed for the integrity assessment of structures, which concern either concrete as a material or the intrinsic state of reinforced concrete. The Ground Penetrating Radar (GPR) is a recognized NDT method, which allows the investigation of the tomography of the material and has been successfully used for the assessment of the current material state and for the localization of problematical regions in existing structures. The GPR technique is based on the transmission of electromagnetic waves, which travel through the target material and the electromagnetic field interaction is being detected. The received reflections of the wave energy depend on the electrical contrast due to difference between dielectric constants of the various materials and on the distance of the interface between different layers from the signal transmitting point. Thus, any significant internal abnormal characteristics of the investigated material can be safely identified. The GPR technique should be combined with other methods to acquire adequate information to assess the integrity of a structure.

https://doi.org/10.2749/222137813806474336

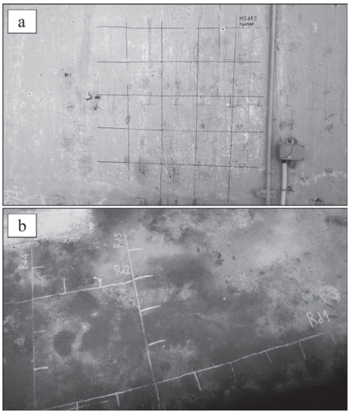

Fig. 1: (a) grid, (b) linear scans

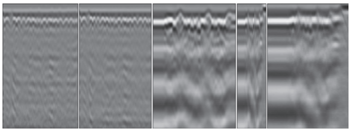
Fig. 2: Effect of scan velocity

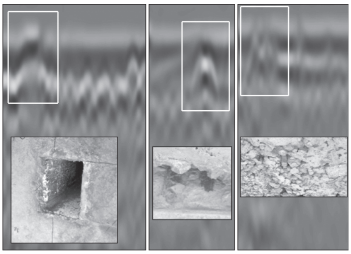
Fig. 3: Special cases investigation

2. Research Scope

The incentive of the present study is the investigation of GPR effectiveness on the structural assessment of existing real structures and the effect of different application methods on the conclusions. The various investigations that are being evaluated in the present study have been performed during in-situ assessment projects on large scale local concrete structures (industrial building, highway tunnel, bridge deck).

3. Experimental Program

Two different antennas have been used: a 1500MHz antenna, attached to a survey wheel and a handheld 900MHz antenna. Suitable main unit settings have been applied, in order to better reflect the embedded reinforcement and the local discontinuities of the material. Two types of scan layout patterns have been applied (Fig.1): a reference grid of various orthogonal sizes (‘grid scan’) and linear scans of various path lengths. The examined variables included: antenna contact to the concrete surface, scan velocity (Fig.2), antenna resolution and scan repeatability. Various special cases have also been investigated (Fig.3): surface discontinuities, concrete spalling and segregation, local rehabilitation with repair material, surfaces exposed to special conditions and different layers with significantly different dielectric constants.

4. Conclusions

The present study aimed to investigate the effectiveness of GPR technique on structural assessment of real structures and to provide potential users with useful hints about its correct application.

It has been observed that, for a given member, high quality results can be obtained by the use of a suitable antenna frequency and the application of carefully selected data acquisition settings, such as recording rate, resolution or pulse gain. However, it is noteworthy that the ability of evaluating the intrinsic state of the investigated member may be significantly deteriorated by the presence of dense reinforcement above any targeted layer. Moreover, even for low reinforcement levels, materials with similar dielectric constants or low thickness may be difficult to identidy and the interface between them may even be completely invisible.

Focusing on the GPR technique application, it should be noted that the scans should always be performed by qualified and experienced users. A good contact of the antenna to the surface of the examined member is considered to be important, though local bounces or regional readjustments may weaken but still not distort the received pulse. As far as the scan velocity is concerned, maintaining a constant velocity is quite important in time mode, as the acquired data may be weak and obscure. In contrast, the velocity is insignificant in distance mode, though considerably high velocities may have minor effects on the resulting images up to some extent, resulting from regional bounces of the antenna.

Finally, one of the most useful advantages of the GPR technique is the high level of repeatability. Thus, significant infrastructure can and should be retested at recursive intervals (e.g. every 3-5 years), in order to detect local deteriorations in time and take the required precautions or measures for rehabilitation. A satisfactory scan pattern for either a recursive or a one-time scan plan may comprise of dense linear scans in predefined paths and be further enriched with supplementary regional grid scans in ambiguous or special regions.