Determination of the Main Wiring Position by Ground Penetrating Radar during the Reconstruction of a Terraced House

Pavel Kovács¹,²
¹Institute of Technology and Business, Faculty of Technology, Department of Civil Engineering, Okružní 517/10, 370 01 České Budějovice, Czech Republic
²University of Technology, Faculty of Civil Engineering, Institute of Building Testing, Veverí 331/95, 602 00 Brno, Czech Republic
kovacs@mail.vstecb.cz

Abstract. Currently, ground penetrating radar (GPR) is commonly used in civil engineering. It can be determined the number and location of steel reinforcement and other subjects in concrete or similar materials. The article is focused on using GPR for determination of the main wiring location. The wall where the main wiring was located were demolished as a part of the reconstruction. By this step the new entrance hall were created. The position and course of the main wiring were determined by GPR measurement. During demolition work were used hand tools in area with installations to avoid the damage. A lower resolution was found when the individual wires were close together. However, the position of the marginal cables was determined with an accuracy of one centimetre.

1. Introduction
Ground penetrating radar has been used for the purpose of testing buildings several years. GPR is a sensing equipment based on the principle of scattering electromagnetic waves. GPR transmits a signal pulse that travels through the material essentially as a nondispersive wave. This pulse is scattered or reflected by any change of impedance. The signal received back looks like the transmitted signal, and its time delay depends on the depth, shape, and electromagnetic properties of the scattering or reflection object [1]. GPR is used in many areas for various purposes as a non-destruction (NDT) diagnostic method. For example, in army, civil engineering, archaeology and many others.

Monitoring underground water leakage pattern by GPR [2], as the example of use in civil engineering. In road engineering is used for non-destruction testing of the road structures [3]. For detecting delamination in concrete bridges was compared GPR with infrared thermography and ultrasonic pulse echo [4]. These devices can also be used for estimation of moisture content in subgrade [5]. GPR is very often used for diameter and cover depth of steel reinforcement [6]. Estimation of ice thickness and the features of subglacial media detected by GPR [7] is the example of non-traditional application.

2. Reconstruction of the terraced house – extension of the entrance hall
The change disposition was designed as a part of the terraced house reconstruction including two apartments. On the ground floor, the entrance hall extension was done. The change of disposition was
based on the demolition of a non-bearing wall made of solid burnt bricks. The original vestibule and warehouse were separated by the mentioned non-bearing wall. The original entrance was confined with a width 1.25 m only. Another disadvantage was minimum storage space (for shoes, clothes, etc.). The interest wall is visible in the Figure 1.

![Image](image_url)

**Figure 1.** Part of the ground floor plan

The main wiring of the house lead through this wall which caused complication during the reconstruction. In addition, both apartments were used during the reconstruction. Therefore, the main requirement of the investor was to keep original wiring until the new one is built. It was necessary to determine the exact position of distribution route to prevent breaches during the demolition.

3. **Determine the main wiring in the wall by GPR**

GPR from Hilti manufacturer was used to determine accurate position of wiring in the wall. Specifically, Hilti PS1000. The first step was to create the image scans (IS) of the wall, in the area of entrance door, in the direction from the top to down. This measurement showed the route of wiring approximately in the upper part of the wall. The second step was to create IS in the direction from the left to right in the upper part of the wall.

The individual IS was created by scanning the area of 600 x 600 mm. Scanning was done in stripes width 150 mm. For the most accurate scanning was used a raster sheet as accessories of the devices. In the first step, scans were made in the X direction, followed by scans in the Y direction. The individual scans were combined, as shows figure 2.

![Image](image_url)

**Figure 2.** Combined image scans of the wall
Figure 3 shows separate IS the right part of the wall. In this IS are clearly visible three routes of wiring and one single wire connected from the top. This image scan shows the position of main wiring, 150 – 350 mm from the upper boundary of scanning area and depth 25 mm under the surface.

![Image scan]

**Figure 3. Image scan**

4. Verification of GPR measurement accuracy – demolition work
All data from GPR were evaluated subsequently the determined position of the wiring was drawn on the existing wall after all demolition work could begin. Hand tools were used in area of electrical installation.

![Exposed wiring]

**Figure 4. Exposed wiring**
Figure 4 shows exposed wiring in the same area as the image scan was taken. Real position of the marginal wiring was identical to measured position by GPR with accuracy to one centimeter. The only difference was number of cables. Five running cables was found in the wall and one cable connected from top (from ceiling light). Depth of wiring corresponded with the measurement as well.

5. Conclusions
The position of wiring was detected by GPR Hilti PS1000. During the subsequent demolition work were used hand tools in the area with installation to avoid the damage. The original wiring was preserved until a new one was made. In the last step old wiring was removed. All was done with the minimization of the time whereas the apartments were without power.

GPR could be used to find old wiring, pipes and other materials in existing structures. A lower resolution was found when the individual wires were close together. In the case of study, it was approximately 30 mm. However, the position of the marginal cables was determined with an accuracy to one centimeter. Investigation of the devices resolution on the depth and mutual distance of the elements in the structure can be the subject of further experiments.

References
[1] A. Benedetto, F. Benedetto, Application field-specific synthesizing of sensing technology: Civil engineering application of ground-penetrating radar sensing technology,” Comprehensive Materials Processing., vol. 13, pp. 393–425, 2014.
[2] T. S. T. Amran, M. P. Ismail, M. R. Ahmad, “Monitoring underground water leakage pattern by ground penetrating radar (GPR) using 800 MHz antenna frequency,” 2017 iNuSTEC Int. Nuclear Science Technology and Engineering Conference., vol. 298, 2017.
[3] K. Pospíšil, J. Stryk, “Možnosti využití georadaru k měření strukturálních vlastností vozovek,” Silniční obzor roč.66., pp. 300–302, 2005.
[4] M. Janku, P. Cikrle, J. Grosek, O. Anton, J. Stryk, “Comparison of infrared thermography, ground-penetrating radar and ultrasonic pulse echo for detecting delaminations in concrete bridges,” Cnostructions and Buildings Materials., vol. 225, pp. 1098-1111, 2019.
[5] L. Sixin, L. Qi, L. Hongqing, et al, “Estimation of Moisture Content in Railway Subgrade by Ground Penetrating Radar,” Remote Sensing., vol. 12, 2020.
[6] S. Hublová, P. Cikrle, O. Karel, D. Kocáb, “Experimental measurement of the diameter and cover depth of steel reinforcement using an electromagnetic concrete cover meter,” Material Science and Engineering. 549, 2019.
[7] L. Jing, W. Shijin, H. Yuanqing, et al. “Estimation of Ice Thiskness and the Features of Subglacial Media Detected by Ground Penetrating Radar at the Bajshui River Glacier No 1 in Mt. Yulong, China,” Remote sensing., vol. 12, 2020.