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COST Action TU1208 – Working Group 1 – Design and realisation of Ground Penetrating Radar equipment for civil engineering applications

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This work aims at presenting the main results achieved by Working Group (WG) 1 "Novel Ground Penetrating Radar instrumentation" of the COST (European COoperation in Science and Technology) Action TU1208 "Civil Engineering Applications of Ground Penetrating Radar" (www.cost.eu, www.GPRadar.eu).

The principal goal of the Action, which started in April 2013 and is ending in October 2017, is to exchange and increase scientific-technical knowledge and experience of Ground Penetrating Radar techniques in civil engineering, whilst promoting throughout Europe the effective use of this safe non-destructive technique. The Action involves more than 300 Members from 28 COST Countries, a Cooperating State, 6 Near Neighbour Countries and 6 International Partner Countries.

The most interesting achievements of WG1 include:

1. The state of the art on GPR systems and antennas was composed; merits and limits of current GPR systems in civil engineering applications were highlighted and open issues were identified.

2. The Action investigated the new challenge of inferring mechanical (strength and deformation) properties of flexible pavement from electromagnetic data. A semi-empirical method was developed by an Italian research team and tested over an Italian test site: a good agreement was found between the values measured by using a light falling weight deflectometer (LFWD) and the values estimated by using the proposed semi-empirical method, thereby showing great promises for large-scale mechanical inspections of pavements using GPR. Subsequently, the method was tested on a real scale, on an Italian road in the countryside: again, a good agreement between LFWD and GPR data was achieved. As a third step, the method was tested at larger scale, over three different road sections within the districts of Madrid and Guadalajara, in Spain: GPR surveys were carried out at the speed of traffic for a total of 39 kilometers, approximately; results were collected by using different GPR antennas provided by the Italian company IDS Ingegneria dei Sistemi; in cooperation with the Spanish company Euroconsult, an instrumented lorry equipped with a curviameter was used in the same road sections. Curviameter and GPR results were compared, with very good agreement.

3. A reconfigurable stepped-frequency GPR prototype was improved and widely tested. The original version of this prototype was designed and realised in Italy, in 2008. In June 2014, with the support of the Action TU1208 (and in particular by exploiting the Short Term Scientific Mission (STSM) networking tool), this prototype was brought to Norway: tests were carried out in laboratory, on roads and archaelogical sites; results were compared with those obtained by using a commercial system manufactured by the Norwegian manufacturer 3d-radar. As a result of this work, it was possible to understand how to improve the Italian prototype. Changes to the hardware were implemented in cooperation with the company Florence Engineering. In the improved version of the prototype, a more advanced technique is used for the reconfiguration of the integration times. In July 2015, by exploiting again the STSM tool, the prototype was brought to Malta: tests were carried out in buildings, churches, archaeological and geological sites; results were compared with those obtained by using a commercial pulsed system manufactured by IDS Ingegneria dei Sistemi. It is worth pointing out that this was the first time GPR measurements were carried out in Malta, where no GPR systems are available. Finally, in January 2016 the improved prototype was again brought to Malta in order to be used during the experimental sessions of a TU1208

Training School. This is an excellent example of a successful scientific activity where STSM and TS COST networking tools were effectively exploited, the cooperation with industry was of central importance, and a less research-intensive Country was deliberately chosen, to test the improved system.

4. A cheap frequency-modulated continuous-wave GPR prototype was designed and realized by an Italian research team; detailled instructions, describing how to build this radar step-by-step, will be available by the end of the Action. The idea behind this initiative is to support and encourage institutes in less research-intensive Countries, who cannot afford a commercial system, to build their own prototype for training purposes and to start familiarizing with the GPR technique.

5. A new stepped-frequency ground-coupled multi-antenna GPR system for road and bridge inspection was developed by 3d-radar (manufacturer based in Norway) and presented during the GPR 2014 conference as a contribution to COST Action TU1208. The starting point was an analogous commercial system, with air-coupled antennas. For road inspection, air-coupled antennas offer practical advantages over ground-coupled antennas (mainly, the possibility to carry out measurements at higher speeds); moreover, they allow enhanced detection of shallow layers inside the road structure. On the other hand, data from ground-coupled array contain much more details from individual scatterers, making them more suitable to image the granularity of the road base materials and for bridge deck inspection, where reinforcement rebar has to be imaged. Ground-coupled GPR systems also provide higher penetrating depth due to a stronger coupling of energy into the ground. The novel stepped-frequency ground-coupled GPR exploits an array of boomerang-shaped monopole elements.

6. Recommendations for the safety of people and equipment during GPR prospecting were produced. Despite the increasing demand of GPR surveys all over the world, safety matters are rarely considered. The Action put efforts into debating them, with scientists and professionals performing GPR surveys. As an outcome of this activity, a book was published where a series of recommendations are provided. These include general hints, recommendations for surveys carried out in challenging environmental situations, description of risks associated to specific applications, instructions for first medical aid, information about GPR electromagnetic emissions and associated risks, and finally suggestions for a safe use of the equipment and for a respectful interaction with the environment.

7. WG1 contributed to the TU1208 Education Pack, an open-access educational package conceived to teach GPR in University courses.

8. Three Training Schools were organised on radar systems and antennas, in cooperation with the European School of Antennas (ESoA): two editions of the Training School "Future Radar Systems: Radar2020" and a Training School on "UWB Antennas, Technologies and Applications". These courses were held in the Karlsruhe Institute of Technology, in Karlsruhe, Germany.

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