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Geophysics in civil engineering

The full potential of geophysics in engineering investigations is yet to be realised. With investigative capabilities ranging from the detail of well-logging to the long traverses of studies of geological structure, the many available techniques can provide important information about the ground, its mass properties, its small-scale variations, and its anomalies of structure or content. The advantage of a geophysical survey is that it enables information to be obtained for large volumes of ground that cannot be investigated by direct methods because of the costs involved. The applications of geophysics in the characterisation of contaminated land, eg the distribution and migration of pollutants in the ground and groundwater, are still developing, but with great potential. These are still insufficiently or inappropriately used in engineering and the newer capabilities are not appreciated. There is a need for up-to-date guidance about how to apply geophysical investigations.

The underlying aims of this report, therefore, are to prepare guidance for civil and geotechnical engineers, and their clients on:

- the integration of geophysical investigations into the design and construction process
- the use of geophysics for determining engineering parameters
- the capabilities of geophysics for investigating ground contamination and grouion.

1.1

ABOUT THIS REPORT

This report was prepared jointly by CIRIA and a working party of the Engineering Group of the Geological Society. In the mid-1990s, the Engineering Group of the Geological Society re-convened the working party to update its report, *Engineering geophysics*, which was published in the *Quarterly Journal of Engineering Geology* in 1988. At the same time CIRIA was actively engaged in fund-raising for a proposal *Civil engineering applications of geophysical investigation techniques*. The opportunity was taken to combine resources and methods of working in order to meet what were largely similar objectives.

The report was compiled by members of the working party, who were commissioned by CIRIA to be the lead authors of specific sections. Two members were usually assigned to each of the main sections. In addition to the Engineering Group working party members, CIRIA appointed Mott MacDonald to draft Chapter 3 on contractual arrangements, the British Geological Survey (BGS) to draft chapters 4, 6 and 9, and Building Research Establishment (BRE) to draft Chapter 10. Following CIRIA's usual practice, a steering group advised the working party and CIRIA staff on the technical sufficiency of the report. Thus the drafting has undergone several stages of review:

- by the sets of lead authors of the sections
- by the working party members as a whole
- by the Steering Group.

In addition, the drafts were reviewed by other experts and users at CIRIA's request and the draft was finally edited by CIRIA staff.

This report is the result of these processes. It embodies the experience and expertise of specialists with the guidance needed by construction and ground engineering

professionals. One of the main purposes, recognised in CIRIA's proposal and a long-term aim of the geophysics specialists, was the need for guidance about setting up the right technical, administrative and contractual framework, to enable a geophysical investigation to be integrated effectively into a civil engineering site investigation.

An increasingly important employment of geophysical techniques is in the characterisation of contaminated land and in understanding changes to the environment of the ground. The need for good practice guidance on this rapidly widening subject, requires a separate section in this report.

1.2

WHAT IS GEOPHYSICS?

In the broadest sense, geophysics is the study of physical properties of the earth. As such, it makes use of the data available in geodesy, seismology, meteorology, and oceanography, as well as that relating to atmospheric electricity, terrestrial magnetism, and tidal phenomena. Applied geophysics has, by means of electrical, magnetic, gravitational, seismic, and other methods, achieved many discoveries of geological and economic importance below the earth's surface [*Chambers Dictionary of Science and Technology*, (ed) T C Collocott and A B Dobson, Revised Edition (W & R Chambers, Edinburgh, 1974)].

This report is about the geophysical techniques that are relevant to ground investigations, and the structural nature of the subsurface for engineering projects and environmental studies.

For two reasons, it is perhaps prudent not to put forward a definition of geophysical investigation:

1. The range of subjects for investigation continues to widen.
2. The techniques that are employed, and what can now be done with them, are developing rapidly.

1.3

BENEFITS AND LIMITATIONS OF GEOPHYSICAL INVESTIGATION TECHNIQUES

Geophysical investigation is an indirect approach to the investigation of ground or built structure. Geophysical techniques can be used, for example, to measure the variation of the physical properties of subsurface materials, eg compressional and shear wave velocities, electrical conductivity and resistivity. Interpretation of geophysical survey data usually requires some prior knowledge of the underlying geological structure. For optimum interpretation of geophysical survey data it is important that adequate direct control is available, which can be provided by boreholes or trial pits for example.

Geophysical surveys can offer considerable time and financial savings compared with borehole investigations. At an early stage of site investigation, it may be beneficial to undertake a reconnaissance geophysical survey to identify areas of the site which should be investigated by drilling, ie those where anomalous results are obtained. On sites where contamination is suspected, a geophysical survey may form part of a preliminary risk assessment, prior to drilling or sampling. During the on-site drilling programme geophysical surveys may be used to check the interpretation of the geological structure between the boreholes. Further geophysical surveys, both within and between the boreholes and on the ground surface, can be used to determine the geological, hydrogeological and geotechnical properties of the ground mass in which the engineering construction is taking place.

Using geophysical techniques to solve engineering problems has sometimes produced disappointing results, particularly when a method, which lacked the precision required in a particular site investigation has been used, or when a method has been specified that is inappropriate to the problem under consideration. In some cases these difficulties could have been avoided by taking expert advice before initiating the survey. In other cases the geological conditions at the site have been found to be more complex than anticipated at the planning stage of the geophysical survey and hence interpretation of the geophysical data by the geophysicist has not yielded the information expected by the engineer. It is often advisable to undertake a feasibility study at the field site to assess the suitability of the proposed geophysical techniques for the investigation of the geological problem.

Once the geophysical data have been obtained, it is possible to produce a model of the geological structure, which gives a realistic correlation with the data. The best overall model is obtained by using all the available geological information from boreholes and field mapping. Without this input of precise information, which includes knowledge of the fundamental physical properties of the geological materials at the site, the model cannot be constrained or evaluated in practical terms. There needs to be close collaboration between site geologists and engineers, and geophysicists in the interpretation of the geophysical data.

1.4 OBJECTIVES OF THE REPORT

This report has several main objectives.

1. To help engineers and engineering geophysicists avoid mistakes of the past.
2. To provide guidance on good practice for the selection, management and reporting of geophysical investigation techniques.
3. To demonstrate the need for an effective reliable team to design, carry out and interpret geophysical investigations.

1.5 REPORT STRUCTURE

The report is structured to present a logical sequence through the process of using geophysics in site characterisation (Figure 1.1). Following this introduction, Chapter 2 provides the background to geophysics as an investigative tool. The procurement, management and reporting frameworks for a geophysical investigation are set out in Chapter 3. This chapter stresses the importance of regular contact with a recognised geophysics specialist throughout the works. Chapter 4 explains the importance of producing a conceptual ground model to enable appropriate investigative methods to be selected. The basic science and general practices of common techniques and some newer techniques are explained in Chapter 5. This is followed by a description of the processes that are used to convert raw field data into a presentable format.

The different targets determinable by geophysical methods are considered in terms of: geological, geotechnical, geo-environmental and structural engineering applications (chapters 7 to 10 respectively). For each application there is a brief description of the nature of the target and what makes it amenable to particular geophysical investigation techniques, with an explanation of their practicalities and limitations. The report cites case examples and references.

The concluding remarks give guidance for practice, particularly on the way that the geophysical investigation should be planned, staffed and managed integrally with the whole scheme of investigation.

1.6

USE OF THE REPORT, ITS SCOPE AND COVERAGE

CIRIA's aim for this report is to promote good practice in the application of geophysics to construction, and this aim is shared by the Engineering Group's Working Party. The report, therefore, is about encouraging dialogue between user and specialist, about options, and about realistic expectations. If it leads to greater interaction between specifiers and those whose work is to be commissioned, between geotechnical engineers and geophysical specialists, and between those interpreting and those obtaining the data, it will be a worthwhile step in making better use of a potentially powerful set of investigative tools.

The report's coverage, however, is necessarily limited. It is not a text on geophysical methods, equipment or data processing, and it does not explain on how to "do" geophysics. Similarly, it is not a text on how to do site investigation. Instead, the intention of the report is to increase the understanding of both.

