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CONTENTS

Chapter 50

Geotechnical reporting

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Geotechnical reports exist in a number of different forms, each with its own distinct purpose. However, all geotechnical reports should be written with an understanding of the project that they have been prepared for and the use to which the report will be put. Geotechnical reports of all forms must be clear and concise, such that the information contained within them is accessible and unambiguous. If the project programme is such that some information to be contained within the report is required urgently, it may be appropriate to produce multiple reports, or addenda to a main report, rather than delay issuing the time-critical information. Since a report can provide useful information long after it was first commissioned it is important to ensure that all reporting is properly archived, and thought is given to how the information contained within the report will remain accessible.

50.1 Factual reporting

50.1.1 Introduction

The primary purpose of a geotechnical factual report is to accurately and precisely describe the ground 'as found': as it occurs *in situ*. While this description should be made with the knowledge that the end-user of the report is likely to make use of the report to design and construct some form of construction, a factual report is not interpretative: the report should be factually accurate and as complete as possible, and not written on the assumption that construction will be of a certain form or use certain techniques. Factual reports are mostly typically the method of reporting site or ground investigations. Such investigation works are often undertaken at an early stage in a project, and the information from the site and ground investigations may result in changes to the layout, nature or methodology of construction of the proposed works. Hence a factual report should always be a complete record of all factual information available, and no attempt should be made to interpret data, or assign design parameters or make design recommendations. If interpretation and recommended parameters are required, this requires completion of an interpretative report (see below).

Thus a factual report should be a clear, concise, complete and accurate description of the ground 'as found'. The nature of this description is dependent on the methods and techniques which have been used to obtain the information which is being reported.

It is important to realise that the true behaviour of the ground *in situ*, and its response to any construction work that may be undertaken which affects it, can rarely if ever be precisely determined through investigation techniques. All methods of inspection, sampling and testing of the soil that are available by their nature are limited to testing a limited volume of soil: this may amount to many tens of cubic metres of soil for *in situ* testing, or as little as a few grams of soil in a laboratory test. However, no test truly determines the response of the entire *in situ* soil mass for the full range of conditions. The difference in volume of soil testing can result in apparently factual data that are inconsistent: for example, it is well known that the factual result of laboratory permeability testing gives a different indication for a soil's permeability than a variable head test undertaken in a borehole. This is a reflection of the scale effects that apply: the structure of a small intact laboratory sample is much less likely to contain large fissures than the volume of soil affected by an *in situ* variable head test, and as a result often gives permeability results two orders of magnitude lower than the field test. Both tests are 'correct' and give factual information; neither necessarily gives an entirely true and accurate value for the soil permeability. Clearly, any report giving the measured permeability of the soil would need to give complete information on the nature of the test used to determine permeability, so that the end-user would have some indication of whether the test was obtained from a small sample or larger soil mass.

Factual reporting also needs to provide complete information about the nature of the techniques used to recover and test samples, since it is necessary to allow for how such techniques may have affected the information obtained. For example, soil and rock core recovered from rotary-drilled boreholes may have drilling-induced fractures which are not indicative of the state of the material *in situ*; methods of sampling can induce stresses and/or deformations in a sample, affect moisture contents and soil suctions, etc. Thus reporting a laboratory test without reporting the method by which the soil sample was obtained may render the entire test worthless, if the result may have been significantly affected by sampling disturbance.

In undertaking factual reporting, there is already much guidance. The majority of ground investigation techniques used on site, and laboratory test methods applied to determine soil parameters, are defined through British standards. These have relatively recently been supplemented or superseded by European standards, which while not identical in their

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requirements, are equivalent in defining methods of undertaking and reporting work. Beyond this, there are national accreditation schemes, applicable to laboratory testing in particular (both geotechnical and environmental), which provide further guidance on the format and content of test reports. Other publications, for example the Specification for Ground Investigation (Site Investigation Steering Group, 1993), also include guidance as to what data should be reported as part of a factual report. However, there are still many techniques or tests where the available guidance is incomplete or absent, and particular project/client requirements or new research leading to changes in the understanding of how a test or technique works may result in the requirement to report factual information in a non-standard manner.

50.1.2 Methods of obtaining details

The information provided in a factual report obviously depends on the nature of the works being reported.

50.1.2.1 Non-intrusive

There are a variety of non-intrusive works that may be undertaken for engineering or geotechnical purposes that require reporting. Most typical would be a simple site walkover. This may be of a relatively small site, but could equally extend to very large worksites, particularly for larger infrastructure projects, where the site may be very linear in nature. Where sites are extensive in nature, the simple walkover may be supported or even replaced by aerial photographic survey. There is also the potential for geophysical surveys to be undertaken, which may be by surface (using hand-held or vehicle-mounted equipment) or airborne. Geophysical surveying may also be undertaken in a marine/overwater environment from boats.

Both the site walkover and the aerial photographic survey are fundamentally visual surveys, aiming to identify and report the same types of features. The intention is to identify and report those features of the ground that constitute potential hazards to the proposed project. Most commonly, this is areas of unstable land: active or relic landslips. Reporting such surveys therefore requires that all indications of current or previous ground movement be identified: distorted fences, tilted walls or trees and slip-scars are all obvious features. Aspects of site drainage are also important to identify, and this can be done through reporting of obvious drains, streams or larger watercourses, including those dry at the time of the survey. However, general geomorphology and land use (particularly the nature of the vegetation growing in a location) may also provide useful indication of the presence or absence of groundwater.

A specific form of visual survey is geological mapping. In many cases, the nature of the underlying geology can be adequately determined by a desk study, but there may be instances where accurate identification of a geological boundary is required.

Thus it can be seen that there is no convenient checklist in completing and reporting a visual site inspection: on one site, the nature of the vegetation may be irrelevant, on another it may give critical guidance to the presence of groundwater. A visual site inspection report needs to be as complete and accurate as possible, and to be undertaken with knowledge and understanding of the proposed project; each site inspection report must by its nature be as individual as the site to which it applies.

Where geophysics methods have been undertaken on a site, the information to be reported clearly depends on the particular method or methods employed. However, geophysical investigations are frequently undertaken and reported by specialist sub-contractors, and the reports normally include some degree of data processing or interpretation. This is acceptable within a factual report; however, the geophysical report should contain all relevant details of calibration applicable to the test, and the full test data from the tests should be included within the report (possibly as an appendix; due to the volume of data, an electronic format will likely be most suitable), such that further analysis/re-analysis of the test data can be undertaken.

50.1.2.2 Intrusive, large-face excavations

'Large-face excavations' refers to any situation where it is possible to view a section through the ground. Most commonly in ground investigations, this is obtained through the excavation of trial pits and trial trenches, for which there are codes and standards defining what should be reported. However, good information on the soil stratigraphy can also be obtained from natural exposures (for example sea-cliffs), and from large-scale man-made excavations. Such excavations may be connected to construction, possibly even the project for which data are being reported, and take the form of large box excavations or vertical shafts, giving a section through the ground from surface. There may also be more linear features at ground surface (cuttings, canals) or at depth (tunnels). Quarries and sand pits (whether operational or closed) also frequently provide potential for inspection of sections through the ground.

Whatever form the excavation takes, certain basic information should always be reported. The codes for reporting of trial pits should always be reviewed for any such excavation, since regardless of how the excavation was formed, it is, in effect, a trial pit. Precise location (in plan and elevation) must be given, along with details of date and weather. The excavation faces should be sketched (with scale/dimensions shown), and it is good practice to include photographs as well. Where samples are taken, it is important to accurately locate where these were taken, showing face of excavation, depth and orientation: again, photography can be useful here, with 'before' and 'after' images of where the sample was taken. Similarly, any *in situ* testing needs to be accurately located. Reporting of large-face excavations should also include details of how the face was created, when and by whom (as applicable). The absence of something within a large-face excavation can often be as important as its presence: for example, any trial pit or trench should generally indicate where groundwater was encountered, and if not encountered then this should be

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expressly stated. In other situations, it may be significant to report the absence of fissuring or a particular stratum, or of evidence of contamination.

50.1.2.3 Intrusive, small-sample size investigations

Intrusive small-sample size investigation invariably means boreholes of some form. There are a variety of techniques for forming boreholes, but any borehole formed for construction purposes should be undertaken broadly in accordance with the British/European standard, and will therefore be reported accordingly. If reporting is to deviate from the appropriate standard, it needs to be specifically instructed. It is important therefore to know what standard the work is being undertaken to and to be familiar with the reporting requirements of that standard, before the work commences on site, so that if variation from the standard is required, it can be instructed in good time.

50.1.2.4 Intrusive, non-sampling: *in situ* testing

In addition to boreholes, which are an intrusive technique that provides for recovery of soil samples, there are numerous methods of undertaking field testing of the soil. These vary greatly in the scale of the sample they test: pocket penetrometers and hand vane tests test a small volume of soil at shallow depth (typically within the wall of a trial pit); cone penetration testing tests a relatively small area of soil, but can test a continuous column of soil tens of metres deep; a plate loading test may be carried out at ground surface or in a shallow excavation, but affects a volume of soil to some depth below the level of the test plate. Hence, the reporting of such testing is specific to the method being applied. Most such field testing is fully defined by British/European standards, which accordingly define the reporting requirements.

While in some cases, the data from this type of test are relatively straightforward to report (for example, a pocket penetrometer), in other cases, considerable volumes of data may be created by the test – for example, pressuremeter tests. These tests require consideration of how all the data can be reported, and often require some degree of electronic/digital reporting as well as any printed report (see section 50.2).

Calibration records, where applicable, should always be included in any field test report. Where the report output is generated by processing of field readings, the actual instrument data should always also be made available as part of the factual reporting, to allow for re-analysis of the data if some discrepancy is detected at a later date. Additionally, any problems encountered during the testing or unexpected results from the tests should be highlighted when reporting *in situ* testing.

It is common for the more complex *in situ* tests (e.g. pressuremeter testing) to be reported in a sub-report appended to the main factual report. The specialist test report is often a combined factual and interpretative report even when submitted as part of the factual report, since the direct output of the tests is rarely in a format that is directly useful to an engineer: the tests may give pressures within the instrument or displacements of parts of the instrument, which are interpreted through appropriate calibration factors to give soil material properties.

50.1.2.5 Specialist down-hole tests

In addition to the range of standard tests that may be carried out during drilling, there are numerous tests that are undertaken after completion of a borehole; typically, these involve some form of groundwater monitoring, including pump tests, variable head permeability tests and packer tests. All these type of tests are well covered by appropriate standards and codes of practice, which include reporting requirements.

Another form of testing that may be done during boring but is often undertaken in completed boreholes is geophysics. These tests generate a variety of data, and therefore the reporting requirement is specific to each test. Typically, however, down-hole geophysics gives data that vary with depth. The data reported should always include sufficient information on the equipment used and details of installation so that the test could be repeated from the reported information. As with *in situ* tests and non-intrusive geophysics, the specialist nature of intrusive geophysical investigations means it is common for the report of the fieldwork to combine the factual information with an interpretation of this information, but for this combined factual/interpretative geophysics report to be included as a discrete sub-section within a factual report. Again, calibration information and raw data from the tests should be included within the report.

50.1.3 Reporting of field techniques

As detailed above, practically all field investigation techniques that may be used and which will hence need reporting are covered by a British and/or European standard, and thus the reporting requirements are fully defined. However, while such standards provide guidance to best practice, variation from them is possible. Regardless of whether a standard is being strictly followed or not, certain data must always be reported.

Any factual report of a field investigation technique needs to clearly state what method was used to obtain the data. Moreover, the actual type of equipment used should also be reported. Different sizes or makes of plant may perform differently, providing different results: for example, it has long been recognised that the type of SPT rod used during a test can affect the result. However, accurate recording of the type of plant and where appropriate the individual rig provides useful quality control on the works, and can be vital in interpreting the data recovered. As a further example, a particular rotary drilling rig repeatedly failed to recover soil core from a particular stratum, while other rigs had no problem. Knowing that it was the same rig that failed to obtain core recovery meant that the areas of ‘no-recovery’ shown on the log could be attributed to a problem with the drilling method, and were not indicative of a true soil condition.

Similarly, the actual operatives of any plant should be recorded: in the above case, different drillers operated the rig,

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so it was known that the problem was not operator-dependent. However, it is possible to see apparent operator-dependent results in some cases: for example, using the same type of plant across the same site, a case has been observed by the authors where SPT results from one driller were consistently and significantly higher than those obtained by a second driller, despite boring in the same ground conditions. The project concerned was undertaken before the routine measurement of SPT hammer energy ratio, and had this form of calibration been available at the time of the works, this may have explained the variation in the recorded data. However, by knowing which driller worked on which borehole, it was possible to account for the apparently inconsistent test data from across the site.

All investigation locations need to be accurately located and orientated (if applicable). Someone picking up the report of the work at any point in the future, be it a year's time or a hundred years' time, should be able to work out exactly where the work was undertaken. For this reason, simple sketches of the worksite on their own are not adequate: the road layouts, buildings, trees, etc. shown on such sketches may completely change if the site is redeveloped, making locating the works impossible; cut or fill operations can change ground elevations by many metres, making it impossible to determine the level of the works.

It is therefore good practice to ensure that all works are surveyed to a recognised datum. Within the UK, the best and most obvious choice is the Ordnance Survey National Grid, since this is well established, widely accessible and unlikely to become redundant within the foreseeable future. Specific project grid/data may be used, but care should be exercised in selecting this option, since details of the project grid may become unavailable in the future (through disposal or other loss of records), leading to the reported information becoming unusable. Where project-specific grids/data are used, it should be clearly stated that the information on location and elevation is to a project grid, and the report should include details of the project grid.

For larger-scale projects, or those extending beyond the boundaries of the O/S (or other) national grid, altitude and longitude information may be provided, along with height above mean sea level, typically determined through use of a global positioning system (GPS). However, even here, there are different systems of mapping and determination of coordinates, so the equipment and methodology used in determining the site position should be explicitly stated.

While sketch plans alone are not adequate, such a sketch, or even better a scalable drawing or site plan, should be included in any report. Such drawings can be particularly valuable where works have some degree of orientation: trial trenches or inclined boreholes, for example, will have a definite orientation, while geological mapping of strata is likely to require reporting of stratigraphic dip direction.

The date of all works should always be given, with the text of any factual report stating the date of the full work period, and individual field test or borehole logs showing the date for that particular operation. Where applicable, times should also be given: an example of where this would be appropriate is where groundwater levels are to be monitored close to a tidal waterway and so may be showing tidal variation.

Weather conditions are also an external factor that should be reported: results of field testing or monitoring may be influenced by temperature, moisture or atmospheric pressure.

Any test or method of investigation reported should always include full records of any appropriate calibration factor that has been applied to the test, and also full records of cleaning, maintenance or calibration of any instrumentation used, if applicable: some instrumentation is capable of showing significant drift from true results if not regularly and correctly maintained, so without the calibration records, the data from such instrumentation cannot be treated as being reliable.

Zero readings and the absence of some material or behaviour should be reported where appropriate. By way of example, any intrusive investigation into the ground capable of identifying groundwater should always state where it occurred, or that it was not encountered. If gas monitoring is undertaken, readings indicating zero concentrations of particular gases should be explicitly reported. Knowing that there is the absence of something may be more valuable than knowing its concentration where it is present.

Individual features of the report by nature must always be tailored to the information being reported. While data such as borehole logs are typically reported to standard scales (often either 5 m a page or 10 m a page), the important thing is that the information is reported clearly and unambiguously. If, for example, the concentration of data obtained from a borehole to be reported makes a 4 m per page scale most suitable, this is the best scale to use, and the scale used should then be clearly stated.

50.1.4 Reporting of laboratory tests

Since the vast majority of laboratory tests are undertaken in accordance with an established code or standard, the reporting requirements are generally also prescribed. However, variations from the standard reporting format may be undertaken where specific project requirements demand it. In such cases, care needs to be taken to ensure that such non-standard reporting is undertaken consistently throughout. It should also be noted that any variation from the established codes/standards reporting requirements will prevent the test being reported as to the standard, even though the actual testing phase was entirely in accordance with the standard. If data are being reported to be supplied to a third party, there may be a requirement from that party that all tests are to a particular standard, so non-standard reporting may render the entire test unacceptable.

Non-standard reporting may be required because of a perceived weakness in the standard for reporting, perhaps because the precision of the standard reporting fails to provide sufficient discretion for the project underway. Alternatively, it may

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represent improvements in the theoretical understanding of a particular test or soil behaviour in general, which has yet to be incorporated into the standards.

As with field monitoring techniques, laboratory tests may have applicable calibration factors that apply to the output data, calibration requirements for the equipment, or method detection limits indicating the smallest quantity that can be detected. Such information should be reported. Where a quantity is less than the detection limit, this should be explicitly reported: it is not correct to report zero concentration, where the test being used is incapable of discriminating between zero concentrations and very low non-zero concentrations.

50.1.5 Reporting of down-hole tests

In addition to the various field techniques and laboratory tests that require reporting, there are a variety of tests which may be undertaken in the field after the main period of fieldwork has been completed. These most typically relate to groundwater, involving tests to determine permeability, and as such the implementation and reporting of these tests is covered by published codes and standards, in the same way as intrusive field investigations and laboratory tests are.

However, such testing may also include geophysical investigations, or geo-environmental sampling and field testing of groundwater or ground-gas. The reporting of such tests may not be covered by established guidance, but may be treated as if it were a field test undertaken during on-site works, with the same requirements to report equipment used, calibration factors, location and orientation, date and weather, etc.

Reporting of field tests undertaken after the main fieldwork period does lead to potential issues over timing of reporting, as discussed in sections 50.4 and 50.5.

50.2 Electronic data

The traditional method of delivering a report, whether factual or interpretative, has been in the form of a bound hard copy. Smaller reports may constitute only a few pages, and be issued as 'letter reports'; large investigations may require reports consisting of many volumes. However, hard copy reports of this form alone are not necessarily the most convenient form for a factual report, since it is not easy to extract and manipulate data. Additionally, producing several copies of multi-volume reports typically requires a significant quantity of paper to be used, which may be at odds with modern standards of good environmental practice. For these reasons, there is an increasing acceptance of the need for electronic data transfer and reporting using electronic media.

The most common form of electronic data transfer in the UK is AGS: that is, data transfer according to the Association of Geotechnical and Geoenvironmental Specialists' Electronic Transfer of Geotechnical and Geoenvironmental Data format (AGS, 1999). This provides a common framework for transfer of geotechnical and geo-environmental data, enabling the data to be readily transferred and manipulated, or input into a database. While in theory, the use of this format means that data can be transferred seamlessly, the reality is that considerable work may still be required in manipulating data before they can be used.

While there is an increasing tendency for laboratories and ground investigation contractors to utilise systems that automatically generate AGS data during the reporting process, this is not universal. Some organisations generate AGS by manually inputting data. As a result, there is the potential for data to be mis-entered, leading to factual inaccuracies and inconsistencies to develop within the data file. There is software available that can check for the latter, but it is very difficult to confirm that factual inaccuracies are not present in the data. Knowledge of how the data are generated is therefore vital, as is information regarding the standard of the quality management system employed by the company or individual generating the data. It is good practice to spot-check any electronic data received against the printed master copy, but if there is any doubt as to the quality control of the data generating process, extensive checking is vital. Such checking is laborious and time-consuming, and unfortunately often not carried out to a sufficient standard. However, no electronic data should be used if there is any doubt as to their accuracy.

While the AGS format is very comprehensive, there are still tests or aspects of tests that cannot be adequately described using it. Geophysics results in particular are not readily reported through AGS. In such situations, it is normally appropriate to use a spreadsheet format for the data. The need to thoroughly check all such data remains.

While electronic data formats allow for rapid and easy data transfer, the real value is in the ability to create databases of project information that can be easily interrogated to enable specific data to be accessed in their entirety and with minimal delay. However, the ease with which data can be extracted means that where a database exists, it may be relied upon to such an extent that it becomes the sole source of data, and the data may not be referenced against the printed master copy. It thus is imperative that where a database exists, it is strictly controlled. While the ability to extract data needs to be limited only to the normal operational procedures of the company involved, subject to any appropriate commercial confidentiality, the ability to input or change data within a database needs to be controlled, and any data to be entered into the database need to have been checked fully beforehand.

The above points refer primarily to use of electronic data transfer/storage of traditional geotechnical factual data. The development of digital technology enables a range of new information to be obtained. For example, it is now possible to obtain digital data from monitoring instruments on rotary borehole rigs, which show factors such as drilling advance rates, rotational speeds and various pressures. Such information appears so far to be principally of value to the drilling contractor while doing the work on site, but may prove to have value in interpreting the ground conditions. Since the use of

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this form of instrumented plant has not yet become widespread, such data are not, at the time of writing, routinely available. However, it illustrates how the range of data that may be available for reporting is not a constant, but will change as technology and methods of working change.

A form of digital reporting that is now routinely encountered is that of the Adobe Acrobat format (PDF files); it is now increasingly common practice for the master hard copy report to be provided in this format also, often directly from the original word-processing software used to create the report. Such electronic reports are very valuable, since they can generally be transferred easily, by CD, datastick or email, and they enable multiple copies of a report to be created and issued without the expense or environmental impact of multiple printed copies. However, a good quality electronic copy of a report requires some degree of processing: this file format allows pages to be bookmarked, such that for example, the first page of each chapter can be found through selecting the appropriate on-screen button. Large reports where this has not been done are considerably less useful than where the report is fully and sensibly bookmarked, since much of the time-saving that can be gained from using an electronic report is lost. While a PDF file provides a convenient form for storage and transfer of a report, the information cannot generally be readily extracted and manipulated, so the provision of a PDF format report can supplement, but does not replace, AGS format data transfer.

Another form of digital data that represents a new form for data to be presented is that of digital photography and digital imaging. Provision of core photographs has long been a standard requirement of any ground investigation involving rotary drilling for core; the widespread introduction of good quality digital cameras has resulted in the majority of such core photographs being provided not just as printed copies, but also as digital image files, which, as with electronic format reports, offers considerable advantages in copying or transferring the images. Care needs to be taken in the use of digital photography that any printed image is a true likeness of the actual soil, since the print is often made using a standard office printer, where the quality of colour reproduction may fluctuate. However, the same issue can occur in developing and printing of conventional film, so is not an issue that prohibits use of digital imaging. Digital photographs also offer the opportunity to manipulate colour or contrast of the image, which can be of great assistance in examining and identifying details of soil structure. Similarly, sample photography is now most likely undertaken with digital cameras, offering the same advantages and limitations as for core photography.

Where digital images are provided, the image file should be named in a sensible and consistent manner, such that it is obvious from the file name what the image shows.

A relatively new variant of core photography is the use of high-resolution core scanning. This generates a high quality image of the entire core, which with the appropriate software can be readily manipulated. The quality and resolution of the image is such that small details of the soil structure can be identified, and the images are far superior to traditional core photography. However, the availability of the scanners is currently limited, the scanning process is more involved than photographs, and requires more resources on site, and the digital size of the images is very large, leading to some problems storing or transferring the images (images cannot be emailed routinely due to their size).

In any form of electronic or digital data storage or transfer, there are a number of issues that must be addressed. AGS is a standard format across the industry, and the widespread use of Microsoft Office software makes it likely that any spreadsheet-based data will also be readily accessible. However, other electronic data formats may require specialist software to enable the data to be viewed/extracted. If the software is hard and/or expensive to acquire, or difficult to use, or consumes a lot of digital storage space on the computer, it may not be possible for all would-be users of the data to run the software. Even where the software is common, care must be taken to allow for different versions of the software. While newer versions of software are commonly written to be compatible with earlier versions, if the data are produced using the latest version of a piece of common software, a user operating an older version may be unable to fully access the data.

This leads to two related issues that need to be considered when considering electronic reporting. If a project is expected to be running over a prolonged period, it is possible that commercially available software used to report data at the start of the project will be upgraded during the course of the works. A decision will then need to be taken as to whether to upgrade the software, and accept that there will be some degree of inconsistency in the project data set, or continue to operate using the older software, which may lead to problems if companies generating the data have updated their systems, or if the software version ceases to be supported by the manufacturer.

Thought must also be given to the long-term availability of any software. Factual reporting from ground investigations is typically used relatively soon after it is generated, but often continues to be of use for many years after. If software is not common, then the problems of having the appropriate software available to access the data are likely to become more pronounced with time. It is possible that if the software operation requires a licence to function and the supplying company has ceased trading, the software will be completely unusable, and hence the digital data will be lost. Even if this does not occur, if data are supplied in an obscure format, it is important to record (non-digitally) what the format and appropriate software to access the data is, such that at any future time, it is possible to identify this and access the data.

Having focused on the potential difficulties of long-term data access due to software, it is appropriate to mention long-term data storage as a further issue affecting reporting. The lifespan of the printed page is well proven: the lifespan of a CD-ROM, or datastick, or magnetic storage tape, is less well demonstrated. If

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digital data are to be archived, thought needs to be given to the environmental conditions in which it will be stored, such that the lifespan of the storage medium is maximised. Consideration also needs to be given to security and back-up copies. Archived data need to be accessible only to those who have authorisation to access the data, but depending on the value of the data concerned, thought should be given to having back-up copies stored separately from the main archive.

One issue applicable, but not unique, to electronic reporting is the need for personnel using software to be adequately trained. Knowing how a piece of software functions makes it less likely that errors will be made in generating/inputting data, and gives the operator a better idea of where problems are most likely to occur. It is important therefore that personnel involved in reporting are familiar with any software being used.

If the software is being used for any sort of analytical or interpretative function, then there is also a requirement to ensure that its operation is adequately validated. Commercial software does not always provide sufficient details or validation of its operation that its use would meet a reasonable quality system without further proof of its reliability.

50.3 Interpretative reporting

Interpretative reporting follows on from the factual report, and provides the manner in which the strictly factual data can be related to the specific project for which they have been obtained. Thus while it can useful to know what the proposed development of a site is to be when preparing a factual report, it is vital for an interpretative report.

The exact content of an interpretative report is, however, still open to some variation: the report may be being produced for a fully scoped and planned proposed development, or the proposals may still be quite vague. In the first instance, the proposals may already have determined that the foundations are to be piled, and the interpretative report is thus required to give guidance on the details of the piles likely to be required; in the latter case, part of the function of the interpretative report may be to provide recommendations as to the basic nature of the foundations (raft, piles, etc.). It is thus important that the requirements of the client in respect of the content and use of the interpretative report are well established and understood.

Interpretative reports are commonly also used to give guidance on design parameters for the soil. Again, where this is to be done, the client's requirements need to be fully understood. Design parameters can be presented as recommended values, design lines (possibly showing variation of a parameter with depth), upper bound and lower bound lines for maximum/minimum credible values, upper bound and lower bound lines for maximum/minimum possible values, etc. The nature of the proposed development and the expected method of design will affect which of these formats for reporting data is required. It is also possible that specific design parameters are not required, only combined plots showing the actual field and laboratory test data, enabling a design consultant to review the data and select their own design values. Alternatively, particular design codes, standards or methodologies may specify how geotechnical design parameters should be selected. The data available may also affect the method of selecting design parameters: many field tests tend to give results exhibiting significant scatter in value, where boundary lines may be more appropriate than a single design line. Conversely, if the available data are very limited in quantity, a conservatively selected single value may be more appropriate.

Interpretative reports also enable details of the factual report to be reviewed and possibly explained. A factual report may contain borehole logs, and such logs may be present on a cross-section, but it is incorrect to interpret the geology between boreholes in a factual report. In an interpretative report, interpreting the geological stratigraphy between boreholes is generally a fundamental part of producing the report, since it provides the understanding of the form and nature of the soil mass. Through such a process, various geohazards may be identified, for example faults identified from vertically displaced stratigraphic boundaries, or buried river channels with possible high volume groundwater flow from unexpected soil types encountered in a borehole. Thus while it is relatively simple to complete a factual report, since it merely requires complete and accurate reporting of all information, the interpretative report is more difficult to complete to a useful standard. It is not an exercise in repeating information from the factual report, but requires an intelligent and informed assessment of that factual information relative to the proposed development for which the information has been gathered. Moreover, the briefing to produce the report may require that it allows for a variety of design methods, construction techniques, building layouts, etc., since all aspects of site investigation and reporting tend to occur early in a project's life when quite fundamental changes to the project may still occur.

Interpretative reports often include recommendations for further investigations, where the assessment of the available factual information reveals deficiencies in the quality or quantity of the available data.

It should be noted that an interpretative report may be combined with a factual report, where the requirement of the report is both to provide full and complete factual information and to include an assessment of the data meeting the standards of an interpretative report.

50.4 Other geotechnical reports

The most common form of geotechnical reports are the factual and interpretative reports that result from some form of site or ground investigation. However, there are a number of other geotechnical reports which may be encountered.

Generally, the discussion of reporting given here is focused on geotechnical reporting only, with some consideration of geo-environmental issues. However, geotechnical issues are not the only concern at many sites, and it is often most efficient to combine all investigation and reporting of a site into one work package. Thus both factual and interpretative reporting may be required to consider factors such as geology and geohazards,

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environmental contaminants (in soil, water and air), broader environmental issues (e.g. flood risk, naturally occurring radon gas) and heritage and archaeological issues (including possible issues of unexploded ordnance). Such issues should typically have been identified in the desk study, and may have been adequately addressed at that stage, but there is the potential for specific site works related to these aspects which will then need to be reported and the implications of what was found will need to be discussed.

The introduction of Eurocode 7 has led to the production of ground investigation reports (GIR) and geotechnical design reports (GDR). The GIR broadly combines the factual report with interpretation to generate design parameters which are then fed into the GDR; the GIR in fact forms part of the GDR. Eurocode 7 defines the format for presenting information, and requires known limitations of test results to be stated, so that users of the data have an indication of their reliability. The GDR provides the foundation design and recommendations that may formerly have been encountered in an interpretative report. It must include the assumptions and data that feed into the design, the methods used in the design, and verification of safety and serviceability. It also requires that supervision, monitoring and maintenance requirements of the completed structure be reported and provided to the owner/client. The specific requirements of the GIR and GDR are stated more fully in EC7.

Geotechnical baseline reports (GBR) are a specialist form of geotechnical report which are produced for commercial rather than technical purposes. They may also be known as ground reference conditions. They draw on and interpret the available data to define baseline conditions relevant to the proposed construction. These baseline conditions are applicable to a specific contract and establish what conditions a contractor should expect to encounter in the ground when undertaking works under that contract. If conditions are worse than these, and the contractor can demonstrate a resulting loss or delay, then a compensation event may be triggered. A GBR must contain statements that are concise, measurable and clearly defined, with no ambiguity or uncertainty, and which are based on a reasonable and realistic assessment of what will be encountered. They define what ground conditions are foreseeable, and hence what ground conditions are unforeseeable, relative to the works to which the report relates. A GBR is not an interpretative report, nor is it a basis for design; it is a means by which the allocation of ground risk is assigned between contractor and client; the ground conditions should normally be stated as accurately as possible: if the conditions are stated to be better than they actually are, the client will be liable to increased claims for compensation; if a worst-case attitude is taken and the ground conditions are described as worse than they actually are, the contractor will assume that there is an increased risk, and will price for the works accordingly, again leading to financial loss to the client. However, in practice, the commercial nature of a GBR does sometimes result in an unrealistic assessment of the ground conditions, reflecting the client's attitude to financial risk.

Another specialist form of geotechnical report is a risk register. In reality, a risk register is not specifically a geotechnical report, since it should apply to all aspects of a project, and list all risks to the project. The risk register is, as its name indicates, a means of identifying and tracking all risks to the project. Typically, the register would detail the nature of the risk, the likelihood of it being encountered and its potential impact on the project, to give an overall risk status, using standard risk assessment procedures. Recommendations as to how to mitigate the risk may then be given, with the party responsible for undertaking the mitigation identified, and the residual risk after mitigation being stated, along with where that residual risk lies. While a risk register is not specifically a geotechnical report, geotechnically related risks are often some of the more significant to a project, due to uncertainty about the ground; hence risk registers routinely require a geotechnical input.

Where field monitoring or instrumentation is installed, there will generally be a requirement for ongoing monitoring. Such monitoring will require to be reported. The frequency and manner in which these reports are issued will depend on the frequency of the monitoring, and the requirement of the project. Typically, following ground investigation works, groundwater monitoring instruments are placed in the ground. Monitoring of these tends to be daily while site works are ongoing, but then becomes less frequent post-site work. Monitoring at monthly or three-monthly periods is not untypical, and while the results of each site visit should generally be provided to the engineer within a day or two of the visit, the contractor would normally only be expected to produce a factual report on the monitoring at the end of the monitoring period. However, monitoring of instrumentation can continue into the construction and post-construction period, in which circumstances, reporting may need to be more formal and frequent. This may require, for example, formal issue of daily groundwater data, or real-time remote monitoring of displacements of a retaining wall. In such cases, reporting is most likely to be electronic, perhaps with a summary printed report periodically. Where this type of data is being generated and issued, it is important to ensure that the critical data are prominent, and that the ability to generate and issue huge quantities of data is not allowed to swamp the recipient of the report, potentially resulting in significant information not being identified and acted upon. The requirements for frequency and format of monitoring reporting will generally be identified in the specification for the broader works.

50.5 Reporting production and timescale

Having considered the nature of what may be reported in a geotechnical report, and how that information may be reported, consideration needs to be given to the practicalities of the report.

A geotechnical report from a ground investigation is often required early in a project's life, and may be a requirement before the proposed design can be progressed. Therefore, the timing of the report is of importance. Where ground investigation works

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are very large, the time required to complete and issue a report may be considerable, as potentially will be the time needed to fully check and correct the report. Allowance needs to be made in any project programme for this time period. In some circumstances, it may be appropriate to issue reports in stages: long-term monitoring by definition is completed many months after the fieldwork stage of a ground investigation is completed, so it would be inappropriate to delay issuing the factual report from the fieldwork until the monitoring is complete. Similarly but less obviously, some laboratory testing (particularly drained tests on clay soil specimens) can take prolonged periods to complete. Where the available laboratory resource to complete these tests is limited and multiple tests are required, it may take several months before this part of the laboratory test programme is completed. In such cases, the demand for basic stratigraphic information may require that these laboratory tests are reported as a later addendum to the factual report.

The programming of production and issue of the interpretative report can also be a significant factor. It is not uncommon for the interpretative report to draw on data from more than one report: there may be a desk study, several phases of ground investigations for the project concerned, and a variety of historical data. As previously noted, the interpretative report is in some ways harder to produce than the factual report, since it is not a simple statement of fact, and therefore may take considerably longer to complete than the factual reports upon which it is based.

When generating a report, it is necessary to consider how many copies of the report are required. It will rarely be sufficient to generate just a single copy for the client: additional copies may be needed by one or more design engineers, and other interested parties (architects, insurers, etc.). However, efforts should be made to ensure only the number of reports actually required are produced, both for commercial and environmental reasons. Production of electronic copies of the report are valuable in this respect, since they allow the report to be readily issued as required, in whole or in part.

In some circumstances, the issue of payment for the report also needs to be carefully considered. The typical factual report from a small ground investigation will be relatively straightforward, and a simple lump sum for its production may be appropriate. However, if the works are larger in scope or undertaken under a term contract and may vary considerably in nature and extent, such a mechanism may be inequable. Allowance for reporting costs to be based on the value of the fieldwork undertaken is in some circumstances appropriate.

50.6 References

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50.6.1 Further reading

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50.6.2 Useful websites

Association of Geotechnical and Geoenvironmental Specialists (AGS); www.ags.org.uk/site/home/index.cfm

It is recommended this chapter is read in conjunction with

- Chapter 9 *Foundation design decisions*
- Chapter 44 *Planning, procurement and management*
- Chapter 52 *Foundation types and conceptual design principles*

All chapters in this book rely on the guidance in Sections 1 *Context* and 2 *Fundamental principles*. A sound knowledge of ground investigation is required for all geotechnical works, as set out in Section 4 *Site investigation*.

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