

Data transfer and the practical application of geotechnical databases

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Abstract

The use of geotechnical database software for handling digital ground data is not new, but recent improvements in computing power have enabled designers to make better use of this technology. This paper describes how a global design office is using geotechnical database software, illustrated by three case study examples. The key benefits are identified, as are some potential pitfalls. Data transfer between organizations is discussed with particular reference to the use of the Association of Geotechnical and Geoenvironmental Specialists (AGS) digital data transfer format commonly used in the UK. Examples are also given where geotechnical databases and digital data transfer have been extended to related applications such as laboratory test scheduling and visualization of pile installation data.

Introduction

Geotechnical database software has been used for the processing of geotechnical and geoenvironmental data for many years. In the UK a system for transfer of digital geo-data between organizations is also well established. This paper describes how different organizations typically use geo-databases and presents case study examples of practical usage from Arup, a global multidisciplinary design consultancy. The emphasis is on practical usage with particular reference to some of the problems faced by data providers and users.

Much of this paper relates to UK practice where the field and laboratory data collection and the interpretation and design are most often carried out by separate organizations. This differs from the norm in some other countries such as the USA and Australia where a single organization will often carry out the investigation and produce the geotechnical evaluation report. The paper generally refers to data collected from geotechnical explorations although similar techniques can and are sometimes used for other types of geo-data such as pile installation and testing results or monitoring data. The scope of this paper is limited to discussion of conventional databases for storage and retrieval of data, which is distinct from the more complex subject of spatial database systems (Geographical Information Systems), although in practice the two are closely related and can often be linked.

Data transfer in practice

Outline of the AGS format used in the UK

The UK geotechnical industry identified the need for a common protocol for transfer of geotechnical data as early as 1991. A working party was established and the first version of 'Electronic Transfer of Geotechnical and Geoenvironmental Data' was published by the Association of Geotechnical and Geoenvironmental Specialists (AGS) in 1992. Commonly known as the 'AGS' format, revisions were published in 1994 and 1999 and the current version (3.1) was published in December 2004.

The AGS data transfer format is very simple. Data are transferred in ASCII format to ensure the widest possible level of acceptance. This format allows data to be viewed in text editors and easily imported into spreadsheet programs and database systems. The structure of the data within the ASCII file is required to conform to a number of rules and a comprehensive standard data dictionary is provided which covers all routine geotechnical and geoenvironmental investigation and monitoring data. Consistent and logical use of defined key fields provides the link between related data in different groups, a concept used in relational databases.

The intention of the AGS format is to reproduce the data that would normally appear in the factual soil boring and laboratory testing report produced by an investigation contractor, with the end user performing any further interpretation or calculation as necessary. The format allows for a degree of customization for non standard data.

UK practical experience of the AGS format

AGS data transfer has been routinely used on major projects since the early 1990s, eg. large highway or railroad schemes. Its use on smaller projects has been inconsistent but is now becoming more common.

The main reason for the relatively slow growth of AGS transfer was problems with the quality of the data provided. In many cases, particularly in the early years, the AGS data files provided by contractors were too often incomplete or incorrectly structured. The most common problem was inconsistent key field data, eg. mismatch between sample reference data in different data groups. The main cause of this was providers, particularly testing laboratories, using spreadsheets or unsuitable software to create AGS data. Specialist geo-database software is much more reliable with respect to data quality as data integrity is more rigorously enforced. When digital data is provided, it is desirable that the same dataset be used for production of both the factual report and the digital data in order to avoid any potential mismatch between the hard copy and digital data. Most current specialist geo-database software is now capable of producing AGS data without difficulty or compromise.

The initial data quality problems led to end users losing confidence in the data received, necessitating time consuming checks and corrections. Data providers responded with more rigorous data checking before issue, but this created delay such that it became the norm for digital data to be issued long after the final factual report. End users were therefore not receiving the benefits of the data until late in the project, negating the primary advantage of digital data transfer. The slow take up of AGS cannot be entirely blamed on the data providers though. Until recently, relatively few design consultants routinely used specialist database software and therefore were not active in demanding timely issue of AGS data. Recent improvements in database software have persuaded many to use it more routinely, thus creating this demand. Data providers are now responding and with most now using specialist database software themselves, the quality and speed of issue use of AGS data has improved significantly in recent years.

Developing areas

The main subject of current development of the AGS format is the proposed parallel version using Extensible Markup Language (XML) for data transfer. Discussion of the benefits of XML is beyond the scope of this paper, but it is noted that many researchers worldwide are working on XML data transfer systems for many different types of data.

As project schedules become ever more compressed, some end users are now demanding digital data during the investigation period. Many design consultants also determine the nature and extent of laboratory testing to be carried out and early provision of field data in digital form facilitates efficient production of testing schedules. Investigation contractors are considering the use of handheld PCs for field collection of data in response to these demands. The methods and hardware for this are already in common use in other areas of the industry, eg. data collection for infrastructure condition assessments. Arup has taken the above a step further by using an AGS style format to transfer laboratory test schedule information. Further information is given in one of the case study examples below.

Use of the AGS format outside UK

The AGS format was developed in the UK for domestic use. However, it has also been used in Hong Kong for many years and Arup is currently working with a major infrastructure organization in Australia to introduce its use in a modified form. An international organization 'DIGGS' (Data Interchange for Geotechnical and Geoenvironmental Specialists) has recently been established with the aim of creating a worldwide standard interchange format. A number of USA based organizations are involved as well as the AGS. The current intention is for the resulting format to be compatible with the AGS data dictionary and GML (Geographic Markup Language).

Use of databases for handling geotechnical data

Use of specialist software

Relational database systems are ideally suited to the task of storage and retrieval of geo-data. It is possible to create a database using conventional database management software, but in practice it is more convenient to use specialist geo-database software. The same types of geo-data are commonly collected across different projects and the specialist geo-databases have predefined structures making them easier to use, although most offer a degree of flexibility. Specialist geo-database software normally includes tools facilitating efficient output of the soil boring logs, graphs, tables and cross sections (fence diagrams). Import and export is usually possible using different formats, including AGS. Some software provides for data manipulation within the database, eg. calculated fields.

Scope of use by data providers

In a UK context the data provider is normally the investigation contractor who will input field data to the database to facilitate production of test pit and soil boring logs and laboratory test reports for the factual report. In some cases the database may be set up to allow the input of raw data with derived results for reporting calculated within the database. Most software allows the AGS data to be output directly from the database.

Scope of use by designers

The end user in the UK will most often be a designer interpreting factual data for design, although it could also be a construction contractor using the data for planning purposes.

In the UK a designer's database will normally be set up to receive digital data in AGS format but in practice it will often be necessary to also input data manually, eg. data from historical investigations or data input in advance of receipt of digital data. The designer's database may contain tables and fields additional to those included in the AGS format to facilitate analysis and interpretation. These may include calculated fields (eg. extrapolated or corrected standard penetration test results) and fields for coding of exploratory hole locations and geological strata.

The outputs that designers most commonly produce from the database are cross sections (fence diagrams) showing the relationship of strata and graphical representation of test data. Logs, tabular output or export to other software are also common. For graphs (and tables) the database allows the designer to filter or sort data according to stratum, location or other criteria using the codings noted above, and design lines can be superimposed.

Plotted output will normally be produced using pre-defined standard templates (reports) created within the software. An example of creating routine plots for the interpretation of a ground investigation is included as a case history below. Production of plots using such templates is often fast and straightforward. However, in many cases the designer will have spent time creating the templates beforehand, the difficulty of which depends on the software. Alternatively, the database can be used to output data, possibly filtered or sorted, to a spreadsheet where graphs can be more conventionally produced. This is commonly done where complex manipulations or post-processing of the data are required. Well designed geo-database software provides a tool for routine use by engineers and geologists that requires relatively little training and no specialist IT skills.

The increasing popularity of geo-databases is leading some designers to extend the use to other related areas, eg. laboratory test scheduling or pile installation data (illustrated in the case studies below). There is also the potential to create direct links between geo-databases and GIS (Geographical Information Systems).

Pros and cons of using geo-databases

Geotechnical data is particularly suited to a database approach because the same type of data is collected most of the time allowing the user to utilize the same database structure and output templates for many different projects. The development of the AGS data transfer format in the UK has led to many organizations having similar database structures, based on the AGS data dictionary. Where large quantities of data are to be manipulated, a database approach is essential to provide the sorting and filtering tools required. Although it is possible to use spreadsheets for manipulation of the data, it is difficult to ensure relational data integrity.

A potential disadvantage of the database approach is the need to recreate output whenever the data changes. Whereas in a spreadsheet the output plots are usually directly linked to the input data, in geo-databases the data are processed using templates to produce output plots which do not retain a link back to the original data. This means that whilst a spreadsheet graph will normally update automatically as data is updated with a database the output must be re-generated via the template every time new data are added. Some geo-database software provides a solution to this problem though. For example, gINT (gINT Software) allows the settings used to generate output with a particular template to be recorded and then re-applied to reproduce the same output when the data changes.

Some problems in the UK arise from the use of stratum (geology) codes. At present there is no standard set of codes, with each organization using its own system which can lead to confusion. In addition, many specifiers will ask the data provider to include stratum codes in the AGS data which is slightly anomalous as this implies a degree of interpretation not normally required. Theoretically the designer should add these codes afterwards but in practice it is much more convenient for the data provider to include codes which the designer can check and edit.

Case study examples

Fulton Street Transit Center, New York

This is an example of how a geo-database can be used to produce routine interpretation output. A ground investigation was undertaken across the site comprising soil borings and rotary coring with insitu testing, sampling and laboratory testing. Access constraints of undertaking an investigation in a busy urban environment meant that the fieldwork was carried out in a number of phases. Initially members of the project team were not familiar with geo-databases, so data collected during the investigation were entered into the usual log production software (WinLoG, GAEA Technologies Ltd) in order to produce a factual report of the investigation.

During interpretation and evaluation of the data it was realized that there would be a benefit from setting up a geo-database. In addition to the general benefits of more efficient data processing and output production that use of a geo-database provides, it also allowed the output created from the data which was available from early phases of the work to be quickly and reliably updated as data from later phases of investigation were produced. During set up of the geo-database the benefit of a common data transfer format was realized, as WinLoG includes a feature to export boring data to an AGS file. This AGS file was then simply imported into a gINT geo-database. This meant that none of the data which were originally entered into WinLoG required manual re-entry into gINT, thus saving wasted effort and reducing the risk of data entry errors. In addition, laboratory test result data, which had initially been compiled into an Excel file, were imported directly into the gINT geo-database. Once the data were successfully imported into gINT, analysis and interpretation was possible.

Initially it was necessary to identify and assign a strata classification to each layer of material encountered in the soil borings. Once this was done, it was possible to compare test results for the same material across different borings. This is where the power of a geo-database is most beneficial. For example, Figure 1 shows a plot of particle size distributions for a particular stratum. Traditionally it would have been necessary to manually identify those samples which were taken from a particular stratum and plot the data together. With a geo-database, the structure of the data tables and options for filtering means that all the grading tests on samples from a specific stratum could be automatically identified and plotted on a single graph. As another example, rather than filtering out specific data to be plotted, differentiation between different data points using different symbols for test results from different strata was required. This is an automated feature of a geo-database, and Figure 2 below shows an example of a plot of SPT against elevation, with different data markers being assigned to tests undertaken in different strata.

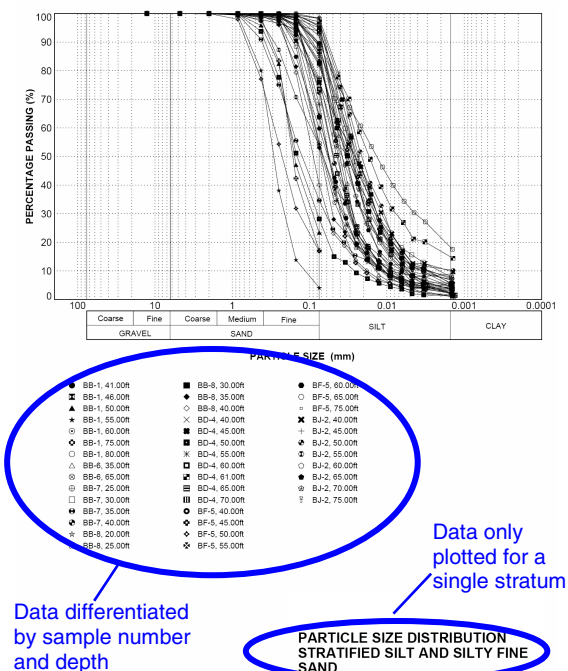


Figure 1. PSD Plot for tests in a single Stratum

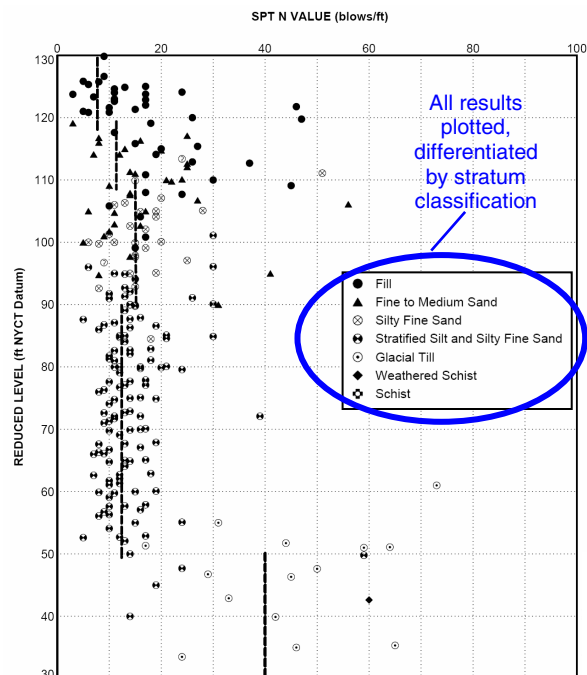


Figure 2 SPT plot, with different data markers to differentiate between strata

Forensic engineering (rock core and pile installation visualization)

Arup commonly use geo-databases for interpreting geo-data on forensic investigations and litigation cases. On a recent project in northern England clear visual representation of data was essential to understand the problem.

The site geology comprised shallow superficial deposits over Carboniferous Coal Measures of interbedded mudstones, siltstones and sandstones of varying strength. A key issue was the nature and strength of the Coal Measures strata at the location of some deep bored pile foundations. In order to provide a visual representation a simple modification was made to the geological stratum coding in the database to differentiate between the rock strengths as described on the core logs. Color was used to represent these strengths on a cross sectional plot, which also included representations of core recovery and rock type. An extract from a typical plot is given in Figure 3 below.

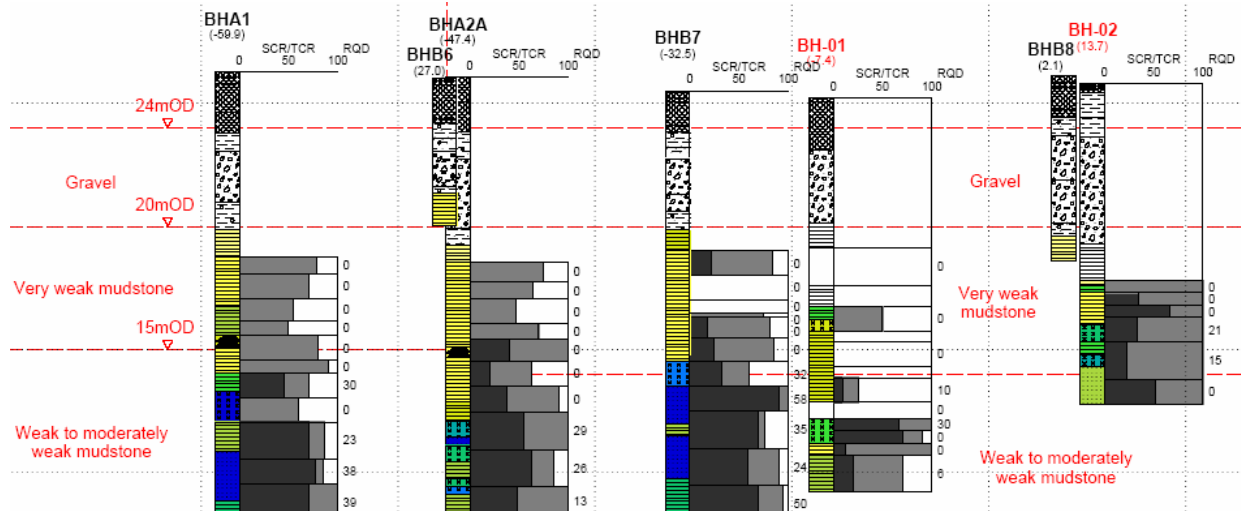


Figure 3 Cross section representing rock type, strength and core recovery

The bored piling had been constructed using the continuous flight auger (augercast) method and rig instrumentation data were available from the installation. The data included records of auger revolutions against bore depth which provides an indication of the difficulty of boring. Selected pile installation data were extracted and input to a modified database which allowed pile installation data to be plotted alongside anticipated geology, as shown in Figure 4 below.

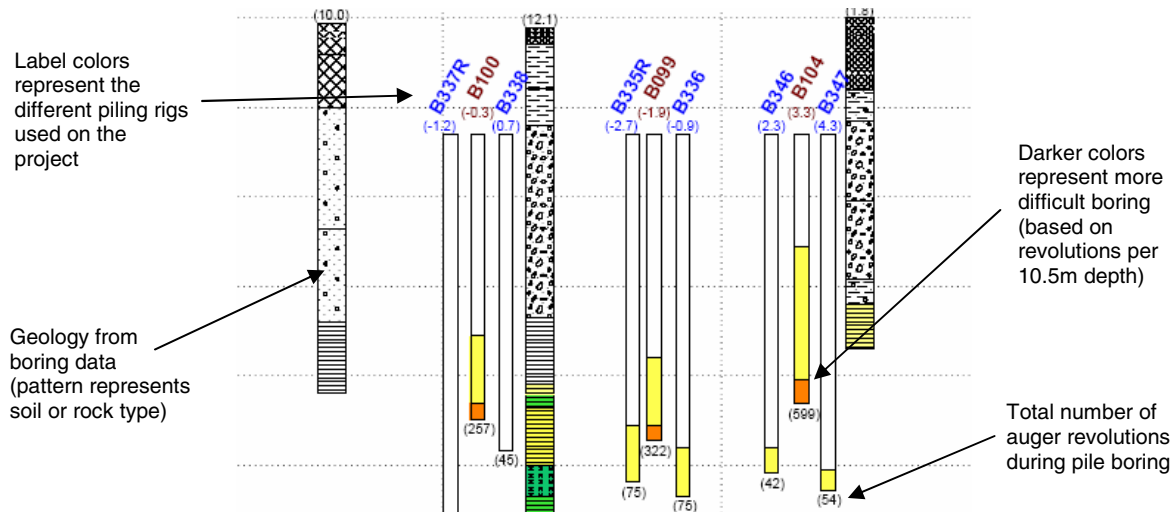


Figure 4 Cross section showing geology and augercast pile installation data

Silvertown Quays, London (AGS data and digital laboratory test scheduling)

This project included a large ground investigation comprising 16 soil borings, 6 rotary drillholes, 32 trial pits, cone penetration testing, pressuremeter testing and extensive geotechnical and chemical laboratory testing. The client required early receipt of data to support an application to the local planning authority. In order to ensure that this was achieved the specification called for provision of preliminary field data (drillers logs) in AGS format within 48 hours of completion of the each exploratory hole.

In order to meet the specification the investigation contractor (Soil Mechanics) elected to input the field data into a geo-database using a notebook PC on site. This data was transmitted to head office and the Arup site engineer. Arup then imported the data into a gINT geo-database and used it to determine laboratory testing requirements.

To further speed up the process, Arup and Soil Mechanics devised a digital transfer protocol for laboratory test schedule information. This used an AGS style format fully compatible with the other data. For Arup this required the addition of two extra tables to the existing database, and some new template reports for output. Soil Mechanics amended their in-house laboratory data management software to allow it to receive and process the digital schedules.

The system adopted also allowed the contractor to return digital schedules in AGS format back to Arup with updates of the status of each test which could then be imported and reviewed. At all stages, hard copy schedules output directly from the geo-database were produced in parallel to the digital schedules.

Overall, the system worked well. The data dictionary for exchanging laboratory schedule information was fairly easy to devise and proved to be robust in use. Initial difficulties with the contractor's software development delayed the issue of test status updates, but the concept was proved.

Arup found that using a digital data approach to scheduling was helpful given the large quantities of data being processed. However, at the time it was found that the geo-database software input interface is not best suited to efficient creation of testing schedules and in practice some of the processing was done in a spreadsheet, with data exported from and imported back into the database as required. As a result, this system has not yet been used on smaller projects. It is likely that conventional spreadsheets and hand written schedules are still more efficient on smaller datasets, with the digital transfer approach being more cost effective for larger investigations. However, this could be addressed by geo-database software writers if there is sufficient demand.

Conclusions

Increasing use of geo-database software can most likely be attributed to improvements in the software. In the UK the well establish AGS data transfer format serves to promote the database approach and its use is increasing now that many data providers are also using well developed database software to produce good quality data. It is noted that there have been recent moves towards creating an international standard transfer format.

Geo-databases can be used to produce the output that designers require in an efficient way. Users with appropriate software and the necessary skills can adapt conventional database structures to accommodate other types of geo-data, and examples of this have been provided in the case studies.

A possible area for future development in the UK is the application of geo-databases and digital data transfer to the subject of laboratory test scheduling, building on the experience of a successful trial. Further software enhancements may be needed to unlock the full potential of this.

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References

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