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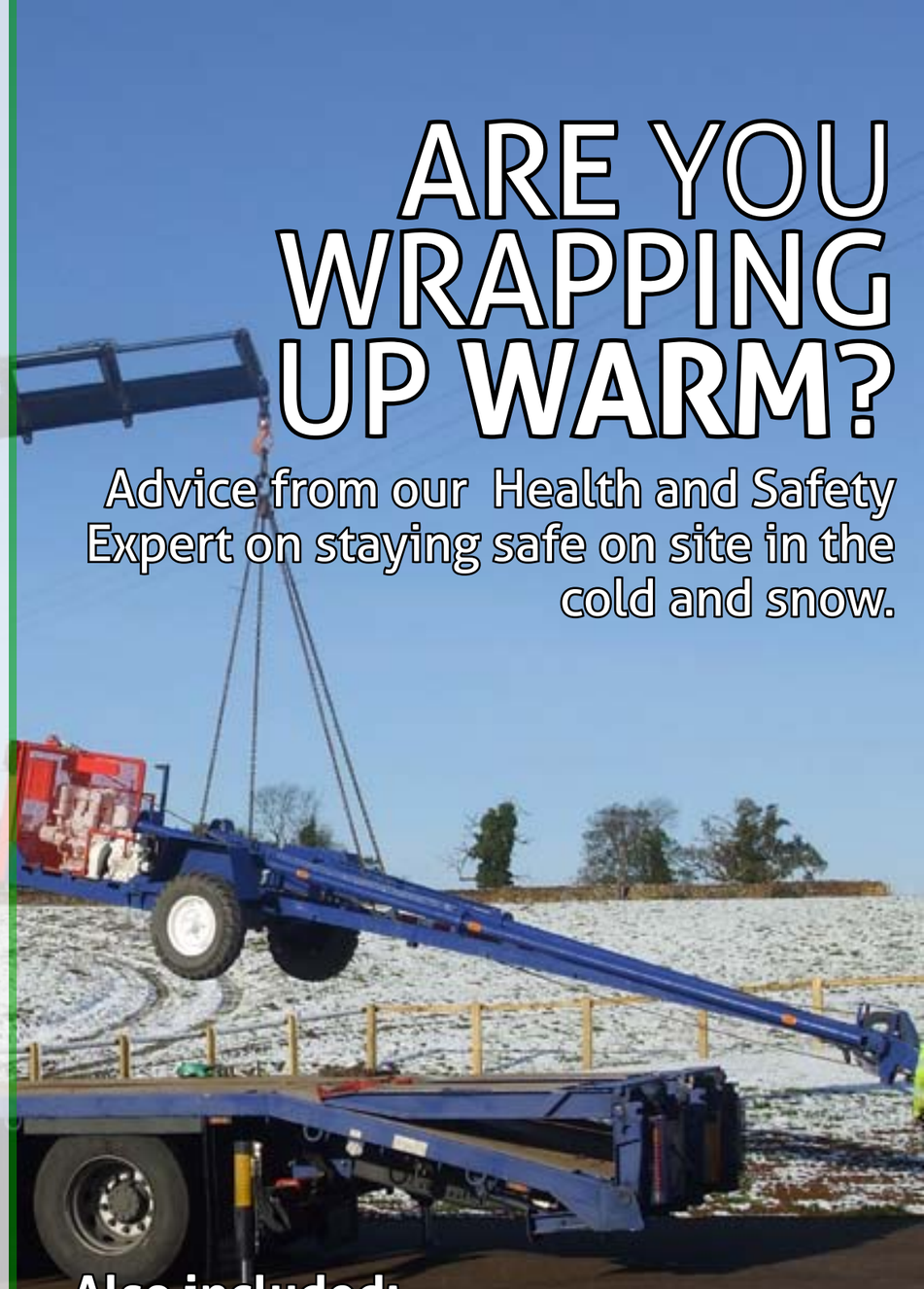

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- Cable Percussion Guarding
- Bender Element Test Analysis
- Geotechnical Knowledge Management
- Normal Background Concentrations

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February 2013

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# Welcome

Welcome to the 18th Edition of **theGeotechnica** - the UK's fastest growing online geotechnically focussed e-magazine.

This month we once again have a number of incredibly interesting and valuable articles. Our cover article this month places a heavy focus on the disrupting and unfortunate snowy weather that we have had to endure recently. Tom Phillips of RPA Safety Services offers his advice on keeping safe in the snow and what you can do to ensure your well-being is maintained in such icy conditions.

Tom's article is not the only must-read section of this month's magazine. We also have the second in our series of articles on geotechnical

site safety. Following on from last month's focus on spatial awareness when operating Cable Percussion rigs, we have an article from the Equipe Group on Cable Percussion guarding - something that is often overlooked in today's Rotary-driven industry.

On page 7 we have an article from GDS Instruments examining the Bender Element Test. GDS have developed Analysis Software for the test and discuss it's advantages against conventional Bender Test Analysis.

Once again we have another insightful article from Alcontrol Laboratories Geraint Williams. This month Geraint's contribution concerns Background Concentrations and what is considered normal in todays climate.

Finally, we have another excellent contribution from Dr Roger Chandler of Keynetix. In this month's edition of **theGeotechnica**, Roger examines Geotechnical Knowledge Management, with a focus on Keynetix Hole BASE SI technology.

We also have entries in the Directory and Jobs sections, with positions available at Geotechnical Engineering as well as Gardline Geosciences.

As with every new edition of the magazine, the Editorial Team here at **theGeotechnica** will be on the lookout for even more new, original and interesting content from all corners of the sector, and would actively encourage all readers to come forward with even the slightest bit of appropriate and relevant content - whether it be a small news item or a detailed case study of works recently completed or being undertaken. If this content is media rich and interactive, then all the better. We are looking to increase the already large readership of the magazine through better social media integration and promotion, as well as improving content month on month.

Once again, for any content that is submitted we will ensure that advertising space, proportionate to the quality of content provided, is available for that single edition of the magazine. From then on, if you have submitted content, you will receive a discount on all further advertisements placed within **theGeotechnica**.

We hope you enjoy this month's edition of the magazine and are inspired to contribute your own content for the coming editions of **theGeotechnica**.

**Editorial Team,**
**theGeotechnica**

# BENDER ELEMENT TEST ANALYSIS SOFTWARE DEVELOPMENT *FOR LABORATORIES*

*Writing for **theGeotechnica** this month are Karl Snelling and Dr Sean Rees, Managing Director and Geotechnical Specialist at GDS Instruments. In this in-depth article Karl and Sean discuss the test analysis software development for laboratories that has been developed to interpret the data from bender element test analysis.*

Bender element testing has become increasingly commonplace in soil laboratories since its introduction in the late 1970s by Shirley and Hampton (1978). The test allows straightforward small-strain stiffness measurements to be made in soil specimens, and can be performed in a wide variety of test systems.

**"To this day however there is still no recognised standard for interpreting the data obtained from bender element tests."**

To this day however there is still no recognised standard for interpreting the data obtained from bender element tests. This fact provided motivation for GDS Instruments, who specialise in providing soil and rock laboratory test systems, to help address the main aspect of subjectivity of the test interpretation – the determination of the shear wave propagation time. This resulted in the development of a user-friendly piece of software to automate the propagation time analysis.

## How does the bender element test work?

Bender elements are made from piezoelectric ceramic bimorphs, and are used in pairs to measure the shear wave velocity in a soil specimen. This involves inserting each element a small distance into the top and base of a specimen, then applying an excitation voltage to one element to generate a shear wave in the soil, as illustrated in Figure 1.

The other element is used to pick up the shear wave that has propagated through the specimen, with its displacement due to the wave inducing a voltage, which is then read by a data acquisition unit. Through knowing the distance between the two elements, and observing the time required for the shear wave to propagate, a value of the shear wave velocity can be obtained. From this point only the specimen dimensions and soil bulk density are required to produce a shear stiffness estimate.

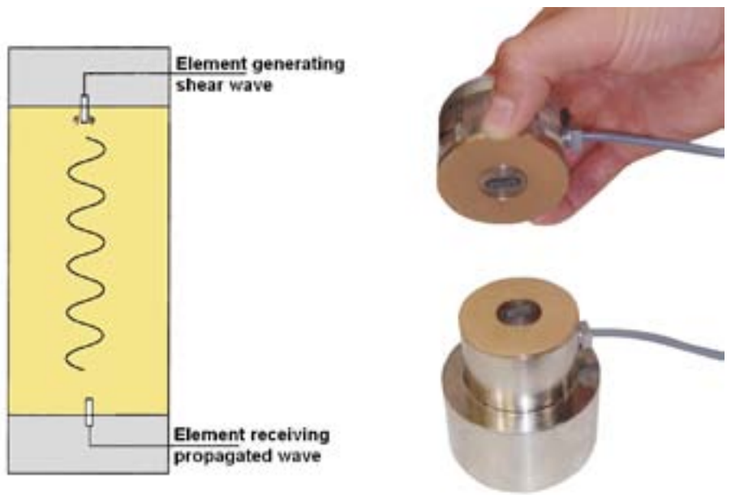


**Figure 1 – Illustration of the bender element test (left); GDS bender elements inserted into a triaxial top-cap and pedestal (right).**

## What complicates the interpretation of bender element test data?

Although the bulk density and distance between elements can be measured accurately in the lab, the time taken for a shear wave to propagate through the soil is somewhat subjective. Consider the idealised received waveform shown in Figure 2 – which point would you say defines the time of shear wave arrival? Further to this, if two engineers agree on using the same point to define the arrival, would they necessarily record the exact same time purely through visual observation of the wave?

**"...if two engineers agree on using the same point to define the arrival, would they necessarily record the exact same time purely through visual observation of the wave?"**

These considerations are of course not recent, with many numerical methods already proposed in the geotechnical literature to objectively determine the propagation time of a shear wave. Such methods typically analyse the test data in either the time or frequency domain, and tend to vary in their complexity.

**"However implementing such methods on a routine basis can often be difficult and time-consuming..."**

However implementing such methods on a routine basis can often be difficult and time-consuming for labs without strong software coding skills, or knowledge of which analysis methods have previously been suggested. The task presented to the GDS team was therefore clear: review the literature, determine the analysis methods available, and develop a simple-to-use software tool that objectively finds the shear wave propagation time in bender element tests.

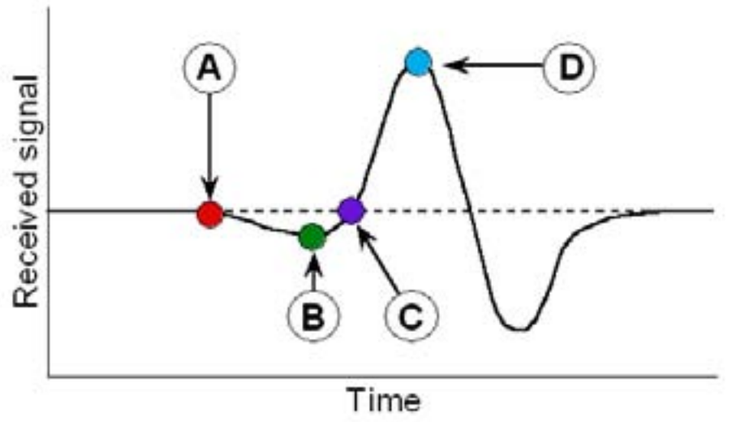


**Figure 2 – Idealised shear wave recorded by a receiver bender element.**

## Development of the GDS Bender Element Analysis Tool

The development process led GDS to create the Bender Element Analysis Tool, or GDS BEAT for short. The tool is unique in that it does not simply settle on one specific numerical analysis method, but instead implements three: objective determination of Point A, B, C, and D via software algorithm, cross-correlation of the generating and receiving element signals, and a cross-power spectrum calculation of the signals to estimate propagation time in the frequency domain. This decision provides distinct advantages to the user, as the hard-work required to process the test data is removed, and a number of propagation time estimates are provided.

Given the tool was developed with the larger geotechnical community in mind, there were two other important specifications: be simple-to-use, and be flexible enough to analyse data taken from any bender element test system, not just the GDS system. Both

**"Both of these specifications were achieved by using Microsoft Excel as the platform, a piece of software familiar to most practicing engineers."**

of these specifications were achieved by using Microsoft Excel as the platform, a piece of software familiar to most practicing engineers. The tool was split into two Excel Add-Ins, each having a specific use – the first allows the user to load one data set into an Excel sheet, then select the various parameter values required to run the analysis, whilst the second permits multiple GDS data files to be simply

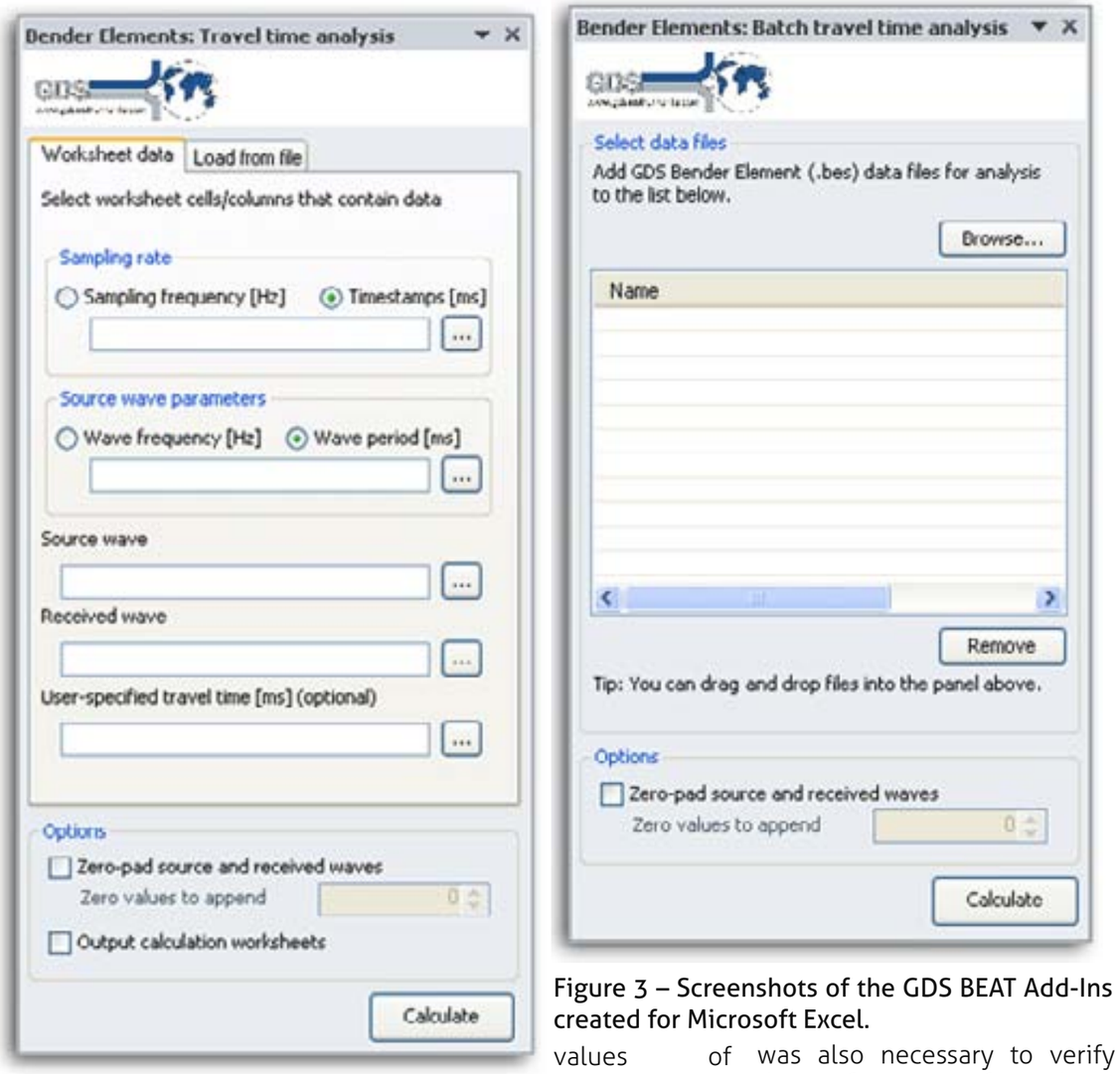


Figure 3 – Screenshots of the GDS BEAT Add-Ins created for Microsoft Excel.

dropped into the tool and batch analysed. Screenshots of each are displayed in Figure 3.

**"It was also important to ensure the analysed data was presented in a clear format, both numerically and visually."**

It was also important to ensure the analysed data was presented in a clear format, both numerically and visually. With this in mind the tool produces two tabs in Excel following the analysis – one listing numerical values of the wave propagation time estimates and analysis metrics, and the other giving visual plots of the recorded element signals relative to the estimated propagation times. Presented in Figure 4, this combination of reporting allows the user to rapidly validate the analysis data, and to further process the information as required.

## How well does GDS BEAT perform?

Developing BEAT was the first step for the GDS team, but it was also necessary to verify the software performed as

**"A triaxial specimen of Leighton Buzzard sand was therefore prepared in a GDS Dynamic Triaxial Test System (DYNTTS)..."**

specified during testing. A triaxial specimen of Leighton Buzzard sand was therefore prepared in a GDS Dynamic Triaxial Test System (DYNTTS), with bender element tests conducted using a GDS Bender Element System (BES) after saturation and consolidation

Figure 4 – Numerical (top) and visual (base) representations of a GDS BEAT analysis.

**"This quickly showed how useful BEAT may be in laboratories..."**

were complete. This quickly showed how useful BEAT may be in laboratories – immediately after saving the bender element data, files were dropped into the tool, with rapid analysis providing on-the-spot estimates for the shear wave propagation time.

While this demonstrated the user-friendly nature of GDS BEAT, further review was conducted post-test to check how accurate the propagation time estimates really were when compared with traditional observation. To do this, the raw test data was sent to an

**"To do this, the raw test data was sent to an academic familiar with bender element analysis, and asked to provide his own estimates..."**

academic familiar with bender element analysis, and asked to provide his own estimates by viewing the generated

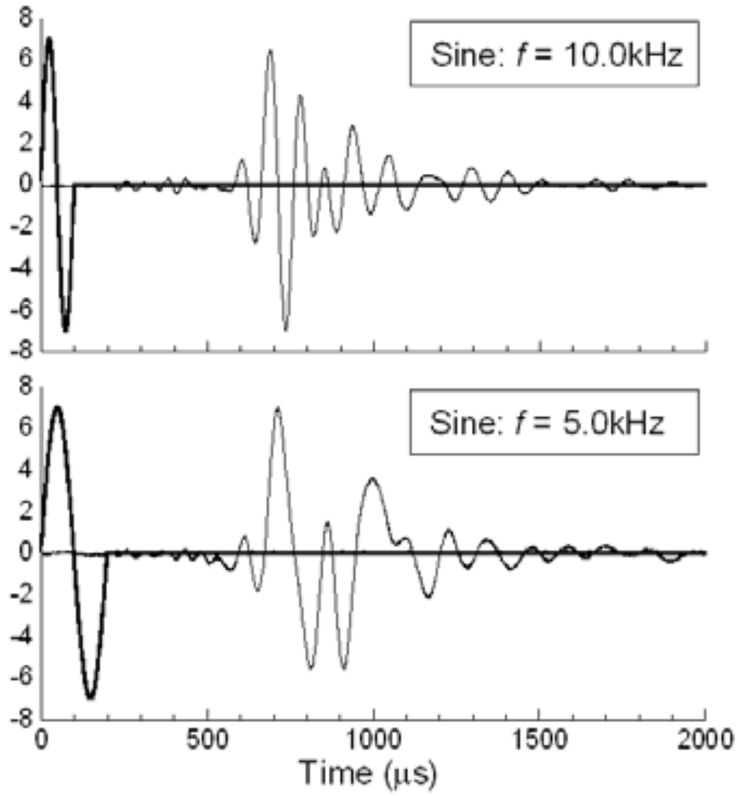


Figure 5 – Leighton Buzzard triaxial test specimen used to verify the performance of GDS BEAT (left); bender element signals obtained from the specimen (above).

**"The agreement between BEAT and the academic was highly encouraging: all but the cross-spectrum analysis method led to shear wave velocities being calculated within a 5 m/s band..."**

and received waveforms. The agreement between BEAT and the academic was highly encouraging: all but the cross-spectrum analysis method led to shear wave velocities being calculated within a 5 m/s band, which is just 2.2 % of the estimated 225 m/s shear wave velocity, when comparing across a sensible range of shear wave frequencies.

Ultimately GDS hope their new software tool, GDS BEAT, will not only be useful for engineers interpreting bender element data, but will also generate discussion within the geotechnical community and contribute in the move towards recognised test standards. For all those interested, further details and video demonstration can be found by visiting www.gdsinstruments.com, along with free download of the software for a limited time only. ■

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Shirley D. J. and Hampton L. D. (1978). Shear-wave measurements in laboratory sediments. Journal of the Acoustical Society of America 63 (2), 607-613.

# GEOTECHNICAL KNOWLEDGE MANAGEMENT

*Dr Roger Chandler, Managing Director of Keynetix and member of the AGS Data Management committee talks to **theGeotechnica** once again. This month, Roger examines geotechnical knowledge management, focusing on the benefits of Keynetix HoleBASE SI technology.*

## Have we been here before?

The more you know about a site and the surrounding area before you start a Site Investigation the better you will be able to design the investigation. Technology has come to our aid here and these days we waste no time jumping on the internet to visit Bing Maps®, Google Earth ®, or Google Street View ® to learn about above ground information and to surf the BGS website and order an Envirocheck ® report to try to understand what may be underground.

These are fantastic resources that have been incorporated into the way we work over the last few years. But more often than not we don't fully benefit from the in-depth knowledge our company already holds.

**"But more often than not we don't fully benefit from the in-depth knowledge our company already holds."**

This is not a new problem. You have probably heard stories of people purchasing their own borehole logs from the BGS or buying the same historical data several times for the same job. So why, when we have all these great resources available to us, do we not make the most of the knowledge our organisation already has?

The four factors that stop us are Time, Availability, Cost and Process:

### Time

The online services have proved so popular because it is very quick to access the information. Aerial photographs in less than 30 seconds and now even the delivery of BGS borehole logs measured in seconds rather than days.

For some companies it is far quicker and easier to use the BGS service to locate their geotechnical information than it is to find it internally, especially if the information is not readily available in the first place.

### Availability

**"If your company's knowledge is held in the head of your senior staff then your team will have severely restricted access to it."**

If your company's knowledge is held in the head of your senior staff then your team will have severely restricted access to it. Following the recent streamlining of our industry you may even find these people have left and there is no way of retrieving what was contained in these heads.

Most companies have a project list somewhere, usually in the form of an Excel spreadsheet, or database. However this data can be difficult to order or filter by geographic location.

The answer that many companies have implemented is a mapping/GIS system. This is the ideal answer but throws up all sorts of other problems, such as cost and process.

### Cost

Everyone is currently very cost conscious, especially when the costs cannot be allocated to a specific project. Many companies find it problematical to purchase and maintain a GIS system as this is a direct overhead, often requiring a software outlay and GIS training for staff.

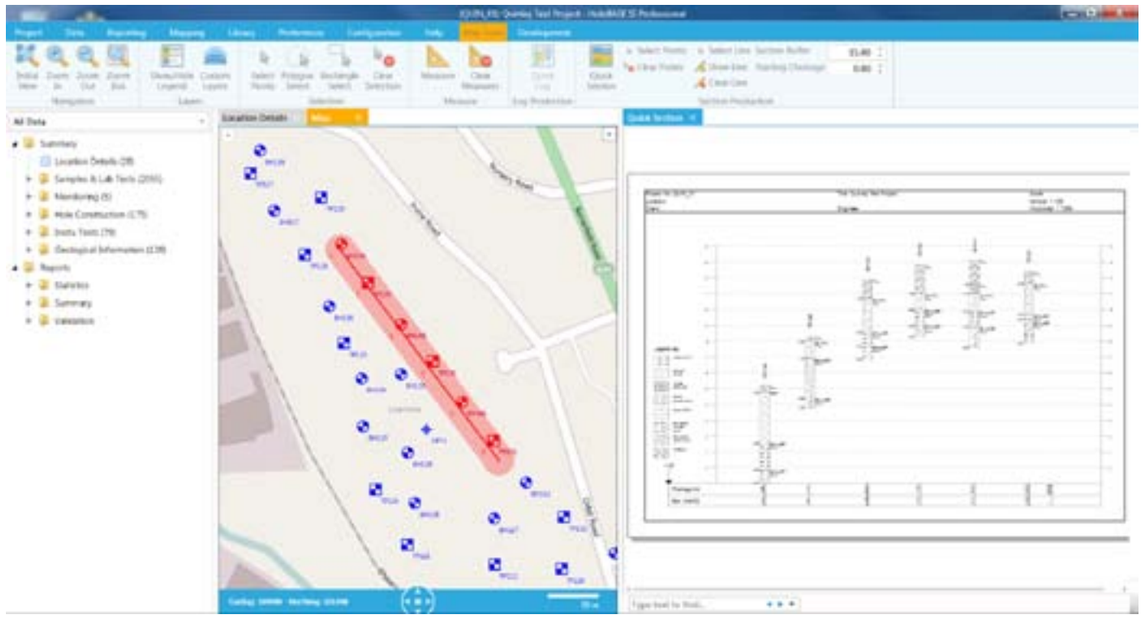
Several companies have side stepped the requirement for their own GIS and have piggy backed off Google Earth by creating a project list KML file that can be opened and plotted in Google Earth. This works well except that it needs additional software to be installed on the machine. It also requires the correct process in place to ensure that the KML file is updated and copies controlled and distributable to everyone.

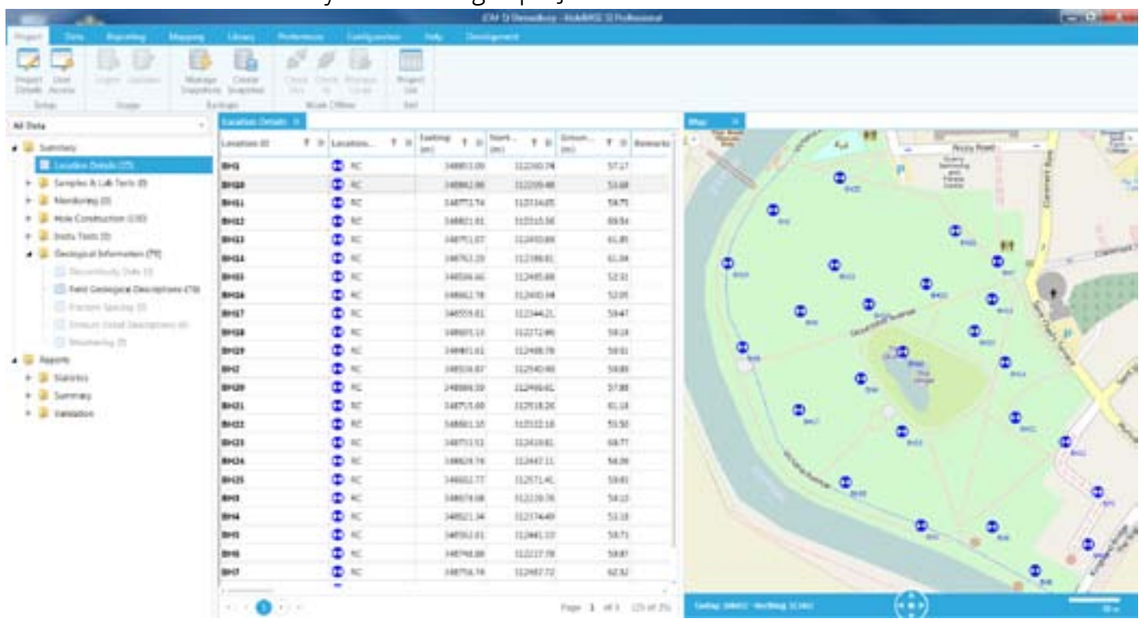
**"This works well except that it needs additional software to be installed on the machine."**

### Process

If the process for keeping your archive up to date includes many steps and additional staff training then the content of the system may fall behind with some projects being missed.

This causes a problem as users will start to lose confidence that all the data is in the system and they revert to the simple spreadsheet solution for tracking project data, if they have more confidence that this is being kept up to date.





**The options**
So the solution is simple. You need an archive system that is built into your processes, costs nothing, available wherever you are and is quick and easy to use.

One such system is the Highways Agency's Geotechnical Data Management System www.HAGDMS.co.uk which many engineers who work for the Agency are already using. Although this does not cost anything to use, it has had significant investment which would be difficult for a small or medium sized organisation to justify.

However, later this month, Keynetix will launch a system that could transform the way you view your archive. HoleBASE SI is an upgrade to the popular HoleBASE 3.1 system and includes a range of tools that allow users to easily locate geographical information from both external sources and your own internal borehole information.

**"These additional features are provided at no additional cost as they are part of HoleBASE SI and are accessible through the same interface used to manage your current site investigation data..."**

These additional features are provided at no additional cost as they are part of HoleBASE SI and are accessible through the same interface used to manage your current site investigation data, produce and read AGS files and plot your borehole logs. It also ensures that projects are automatically added to the archive system to ensure the process is maintained.

The new system also enables you to import your existing project list very easily so it appears to tick all the boxes the industry needs.

Time will tell, but it certainly looks like Keynetix have produced a very exciting upgrade to their popular product that will transform the way we view our organisation's own geotechnical knowledge and make it much easier to answer the question "Have we been here before?"

For more information on HoleBASE SI please visit www.keynetix.com/holebase

# GUARDING FOR CABLE PERCUSSION RIGS

*This is the second in a series of articles on safely managing all working geotechnical sites, penned for **theGeotechnica** by the experts at the Equipe Group. This month we focus on safely guarding cable percussion rigs, as well as a brief examination of PUWER and LOLER regulations.*

Following on from last month's advice about the necessary spatial awareness required when working with Cable Percussion (CP) rigs, we should now be able to get our rig to our borehole position safely. The next question we must then ask ourselves is: How do we ensure that the rig itself is safe to use? One of the most important components of CP rig use has been overlooked in recent years - the guarding. Recently the focus of the industry has largely been on Rotary rigs and the guarding of their dangerous rotating parts; however Rotary rigs are not alone in having a number of dangerous moving parts.

**"The next question we must then ask ourselves is: How do we ensure that the rig itself is safe to use?"**

Cable Percussion rigs also have a number of equally dangerous moving parts, and these parts all fall under the same PUWER (Provision and Use of Work Equipment Regulations 1998) as our Rotary rigs and therefore must therefore be guarded correctly to enable the rigs to be operated safety.

### The Engine

Most modern rigs have electric start engines with recessed starting handles, so guarding is unnecessary here. However older rigs such as the one displayed in Figure 1 have exposed shafts - these must be guarded. The shafts should be completely covered to prevent entanglement when starting the engine. Failure to have proper guarding in place can be dangerous. The shaft can easily be covered and guarded, as seen here in Figure 2.

### The Winch

There are two parts of a Cable Percussion rig's winch that must be guarded: The open winch itself and the winch shaft. The winch itself must be guarded, again to prevent entanglement. Figure 3 shows us a simple method of guarding the winch, which does not affect the operation of the rig in anyway.

**"The winch shaft must be guarded as the rotating shaft could cause injury - it can again be covered without affecting the operation of the winch."**

The winch shaft must be guarded as the rotating shaft could cause injury - it can again be covered without affecting the operation of the winch. Figure 4 demonstrates a simple guard that is available for retro fitting to all ages of cable tool rigs from manufacturers.

### Capstan Winches

Although only found on the Dando range of CP rigs, these open winches have no place on modern drilling sites - the skills needed to operate them have long since become unnecessary. Despite this they are often left completely unguarded but never used, as shown to the right in Figure 5. To pass a PUWER Inspection they should be permanently covered and not used, as currently there is no safe method of operating this open winch whilst adhering to current guarding regulations.

**"To pass a PUWER Inspection they should be permanently covered and not used..."**

Figure 1 - Unguarded shaft.

Figure 2 - Guarded shaft.

Figure 3 - Simple winch guard.

Figure 4 - Retro fitted winch guard.

Figure 5 - Unguarded capstan winch.

**Gearboxes and Chain/Belts**
These will have been guarded by the manufacturer from new,

**"...any evidence of the gearbox or drive chain being exposed during operation constitutes the operator having either modified or removed the guard - both of which are illegal."**

therefore any evidence of the gearbox or drive chain being exposed during operation constitutes the operator having either modified or removed the guard - both of which are illegal. If this is the case, the rig should not be used and removed from the field.

There is however one very dangerous area of the Cable Percussion rig which currently cannot be guarded and that is the drill string itself at

**"...without guarding present we should ensure that there is a safe method of work in place and that the Lead Driller and Support Operative can both prove their competency in their role."**

the borehole. Here, without guarding present, we should ensure that there is a safe method of work in place and that the Lead Driller and Support Operative can both prove their competency in their role.

It is essential to always ensure that all moving parts which have the potential to cause injury are completely guarded before starting to use the rig on site. Remembering which components of CP rigs need guarding is quite simple: If it is moving and could cause injury, then guard it.

**LOLER**
The subject of LOLER (Lifting Operations Lifting Equipment Regulations 1998) has been covered in an earlier addition

**"...it is still abundantly clear that some companies do not understand or indeed enforce these basic standards."**

of **theGeotechnica**, but it is still abundantly clear that some companies do not understand or indeed enforce these basic standards.

In simple terms, every part of a drilling rig which relates to the lifting falls under the LOLER Regulations and therefore needs to be examined. In the case of a drilling rig itself this examination must be carried out every 12 months. However

**"...accessories such as swivels, sinker bar loops, snatch blocks, and safety hooks (etc.) should be examined every 6 months..."**

accessories such as swivels, sinker bar loops, snatch blocks, and safety hooks (etc.) should be examined every 6 months to ensure that they are compliant with the regulations. This is again quite simple to check; ask yourself what is the main purpose of the piece of equipment? If your answer starts with or includes the word 'LIFT' it will undoubtedly fall under LOLER.

**"Currently all pieces of equipment inspected under LOLER must carry a unique ID, so if you are unsure whether something has not been inspected then look for the ID."**

Currently all pieces of equipment inspected under LOLER must carry a unique ID, so if you are unsure whether something has not been inspected then look for the ID. If a piece of equipment has no ID then it has NOT been inspected and should not be used under any circumstances. On the other hand, if you do find the item's unique ID then check it against the certificate administered by the competent person(s) who carried out the

**"This certificate should always be available for inspection."**

inspection. This certificate should always be available for inspection.

Hopefully this guidance has given you an overview of what to be wary of when examining your Cable Percussion rigs for compliant guarding. If you require any further information, please contact the Equipe Group.

Next month we will be examining geotechnical sampling and testing best practices. ■

# WRAP UP WARM, IT'S COLD OUTSIDE!

*Writing for **theGeotechnica** once again is Tom Phillips of RPA Safety Services. This month Tom imparts some valuable health and safety advice for those of us working outside in cold and snowy conditions.*

HSE Principal Inspector of Construction, Peter Black, has recently been quoted as saying "For those working outdoors, the winter months bring additional challenges to keeping safe. Cold weather and shorter periods of daylight mean there is more potential for accidents to happen. With a little planning, and common sense, these can be avoided." So what do you need to look out for?

**"Cold weather and shorter periods of daylight mean there is more potential for accidents to happen."**

### Moving vehicles

These are a major hazard in the geotechnical industry where, unlike the majority of construction activities, it is not deemed reasonably practicable to provide vehicle segregation and demarcated walkways. It is therefore vitally important that all staff take responsibility for their actions on dynamic sites.

To this end, operators of construction plant such as diggers, telehandlers etc must ensure they regularly clean their windows so they can safely see all around. This should be combined with constant use of mirrors and a banksman where appropriate. Lights on all vehicles should be cleaned regularly to ensure vehicles are visible at all times, and vehicle depots and marshalling yards should be well lit and gritted to avoid slip and trip hazards.

Workplace transport accidents account for many of the deaths and injuries investigated by the HSE every year. Many of these occur in the winter.

### Welfare

In winter it is important to ensure that water supplies do not freeze to ensure adequate drinking water and that any gas heaters provided, have adequate ventilation. Portable chemical toilets should only be used for short duration projects and here appropriate, provision should be made for drying rooms for wet clothing. Hot water for washing is even more important than usual.

### Hand Arm Vibration

People who are exposed to vibration from power tools should improve their blood circulation by keeping warm and dry, where necessary wearing gloves, a hat, waterproofs and heating pads if available. Stopping smoking improves blood circulation, as does massaging and exercising fingers during work breaks.

**"Stopping smoking improves blood circulation, as does massaging and exercising fingers during work breaks."**

### Lone working

Those who have staff carrying out lone working, must always ensure they have a suitable, robust procedure in place to make sure lone workers are safe. In winter this is even more vital. Ask yourselves:

- If a worker fell and broke a leg in a remote location in the dark, how would they summon help?
- Who would be responsible for ensuring they had returned home safely at the end of the day?

Recent cases, including the tragic death of a gamekeeper, have highlighted the vital importance of ensuring lone workers are protected and have the communications they need during winter months.

### Chilblains

A painful and debilitating injury, chilblains are caused by the repeated exposure of skin to temperatures just above freezing. The cold exposure causes damage to the capillary beds (groups of small blood vessels) in the skin. This damage is permanent and the redness and itching will return with additional exposure. The redness and itching typically occurs on cheeks, ears, fingers, and toes and is regularly suffered by outdoor workers.

**"The cold exposure causes damage to the capillary beds..."**

Stopping smoking during working hours and avoiding caffeine based drinks or decongestant medicines, all help to improve blood flow and keep the skin temperature raised. Having at least one hot meal a day also helps, as it helps warm the body.

Those at risk, particularly diabetics, should be encouraged to check their feet regularly, to put on warm clean socks at regular intervals and moisturise skin to prevent cracking of the skin.

So there you go - a few simple tips to keep everyone safe on site this winter. But I'm sure that given the variability of the UK weather, it will be tropical outside as soon as this is published. ■

*In this latest article from Geraint Williams, Alcontrol Laboratories' Senior Environmental Scientist, Geraint writes for **theGeotechnica** on the subject of new studies carried out by the BGS into normal background concentrations.*

# WHAT ARE NORMAL BACKGROUND CONCENTRATIONS?

The Department for Environment, Food and Rural Affairs (Defra) commissioned the British Geological Survey (BGS) to provide guidance on normal background concentrations (NBC) of contaminants to support the revised Statutory Guidance. The project was intended to provide significant cost benefits to Local Authorities by simplifying guidance to make investigations more cost-effective. It was also intended to reduce regulatory uncertainty and is consistent with a drive to focus attention on higher risk sites. BGS's published work now provides a systematic and transparent method for defining NBCs. It has delivered technical guidance on the distribution of arsenic, cadmium, copper, mercury, lead, nickel and benzo(a)pyrene.

**"BGS's published work now provides a systematic and transparent method for defining NBCs."**

Normal presence of contaminants is referred to in section 3.2 of the Statutory Guidance: "Normal levels of contaminants in soil should not be considered to cause land to qualify as contaminated land, unless there is a particular reason to consider otherwise" (para 3.2.2).

Normal levels may result from:

"(a) the natural presence of contaminants at levels that might reasonably be considered typical in a given area and have not shown to pose an unacceptable risk to health or the environment;"

"(b) the presence of contaminants caused by low level diffuse pollution and common human activity other than specific industrial processes. For example, this would include diffuse pollution caused by historic use of leaded petrol and the presence of benzo(a)pyrene from vehicle exhausts ...that might reasonably be considered typical (para 3.2.3)".

The series of reports produced by BGS go on to explain how NBCs should be used in the context of Part 2A.

The NBC project was undertaken in four work packages, the initial packages (WP1 and WP2) were the data gathering and data exploration phases, relying largely on the Geochemical Baseline Survey of the Environment (G-BASE) and the National Soil Inventory (NSI). NSI samples cover all of England at a density of one site per 25km2. G-BASE samples are collected at a higher density - urban samples at four sites per km2 and rural samples at one site per 2km2. However, the G-BASE sample coverage is only for central and eastern England. These data sets were also supplemented by other less densely sampled surveys which, in combination, provide information about how contaminant concentrations varied with depth and between different analytical methods. The final report states that only samples collected systemically were included in the work to estimate NBCs.

As there is spatial variability in the distributions, the approach of the project was not to apply a single national NBC but to delineate the principal areas of the country where the important controlling factors can be identified and a NBC calculated. The term domain was used

to identify areas where high concentrations of a contaminant can be attributed to readily distinguishable controlling factors. The three main controls were determined as: the underlying parent material upon which the soil has formed; non-ferrous metalliferous mineralisation and associated mining/processing activities;

**"The area remaining outside domains, defined by these controlling factors, is referred to as the Principal Domain."**

and urbanisation. The area remaining outside domains, defined by these controlling factors, is referred to as the Principal Domain.

Information on As, Cd, Cu, Ni and Pb is derived from a very large data set, though when subdivided into domains, some domain NBCs are only based on a small number of samples. Fewer overall data points for Hg and BaP were available to use in the data exploration phase. In the case of BaP, data from Wales and Scotland was used to calculate NBCs. Asbestos, initially considered with the contaminants above, was not explored further because it was recognised there was insufficient information available on naturally occurring asbestos minerals. The reports highlight where there are gaps in knowledge but the methodology allows for recalculation of NBCs, to greater levels of confidence, when more data becomes available.

A statistical methodology was developed to quantify NBCs and generate percentage information. Percentiles for the domain data sets are generated along with calculations of percentile confidence intervals. The upper limit for a NBC has been defined as the upper confidence limit of the 95th percentile. The final work package produced a series of Technical Guidance Sheets (TGS) with accompanying supplementary information for each contaminant. Other percentiles are listed in the TGS supplementary information – where it may be useful to consider the definition of normal levels in the context of other statistical information.

The project has delivered readily available information in the form of TGS for NBCs, GIS resources (domain polygons) and supplementary data. A full understanding of the derivation of NBCs is required and they should not be used as simple look-up tables. Awareness of where there are gaps in knowledge is important. It is evident that further data is needed for BaP and Hg. It is also clear that NBCs are needed for more priority contaminants, although this work provides a statistical methodology for others to use at a more local scale or to determine NBCs not previously investigated (providing there is systematically collected results of appropriate quality). NBCs were not originally intended to be used in the context of the planning, however on the back of this work, local authorities can inevitably expect challenging debate with consultants.

**"Awareness of where there are gaps in knowledge is important."**

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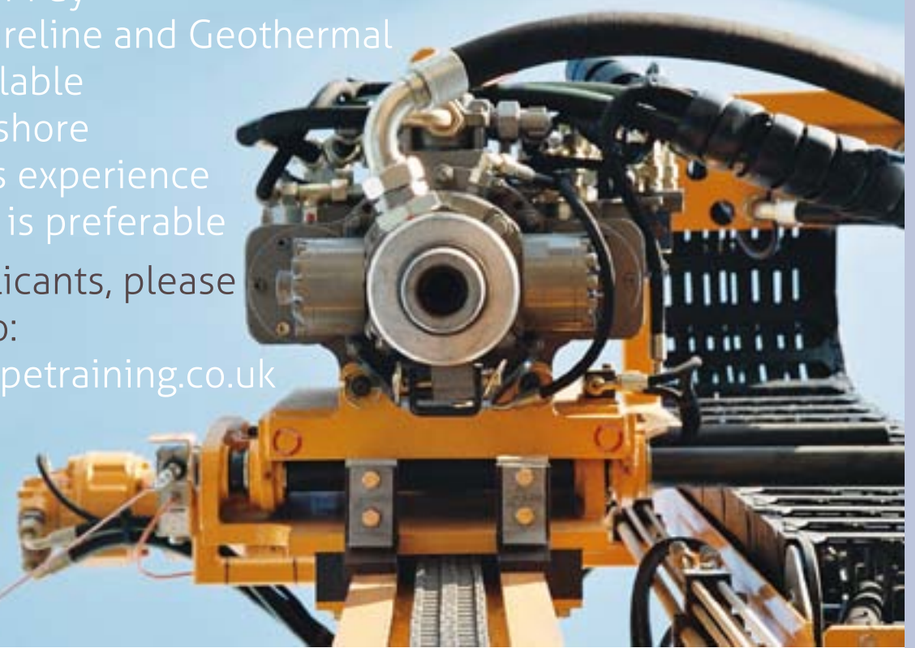

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