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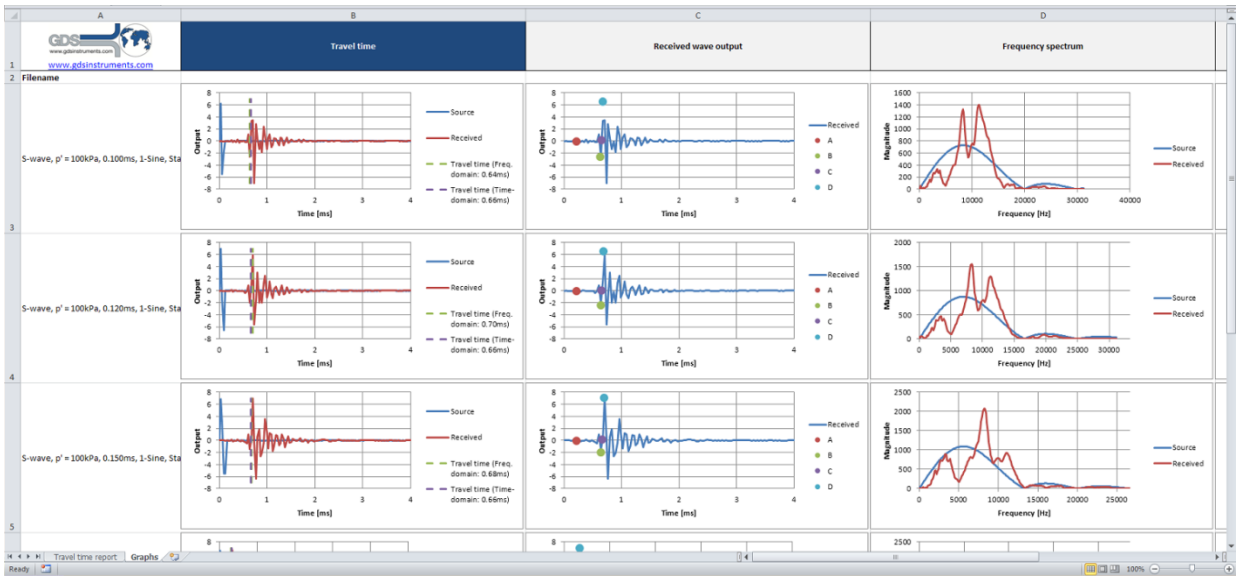
World Leaders in Computer Controlled Testing Systems for Geotechnical Engineers and Geologists

GDS BEAT – Handbook

The GDS Bender Element Analysis Tool Handbook



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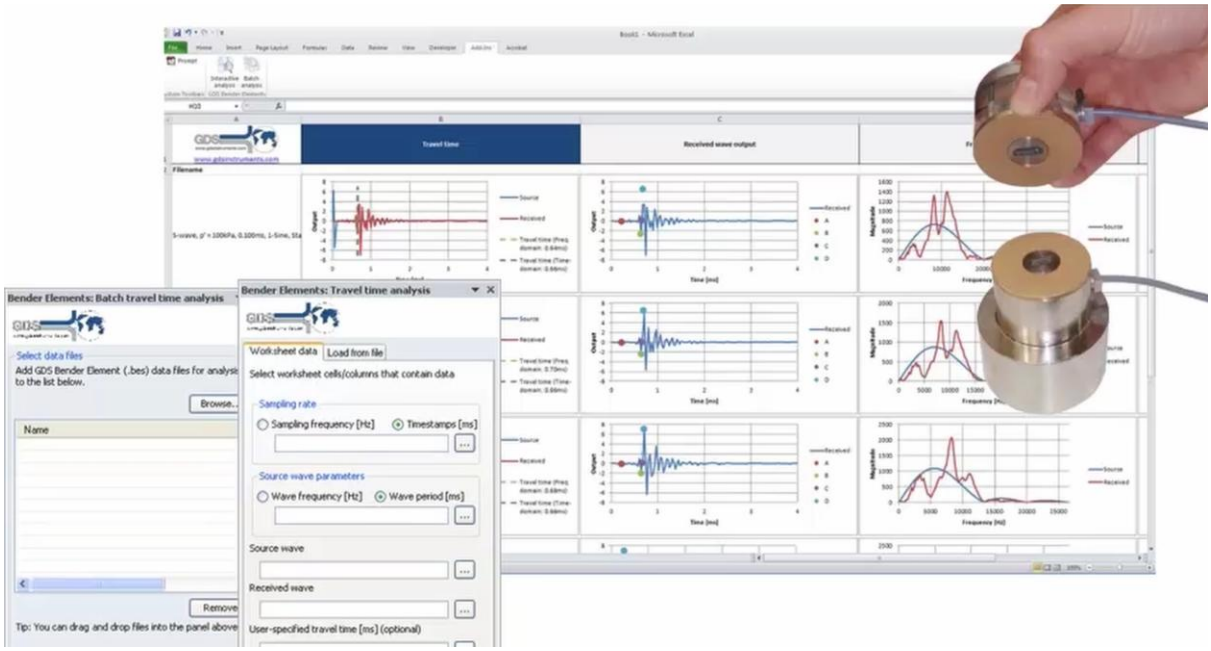
GDS BEAT (2024)

1. Introduction

This document provides explanations of the GDS Bender Element Analysis Tool, a free to download tool developed by GDS Instruments to allow the rapid, automated analysis of Bender Element Tests to objectively estimate the shear wave travel time.



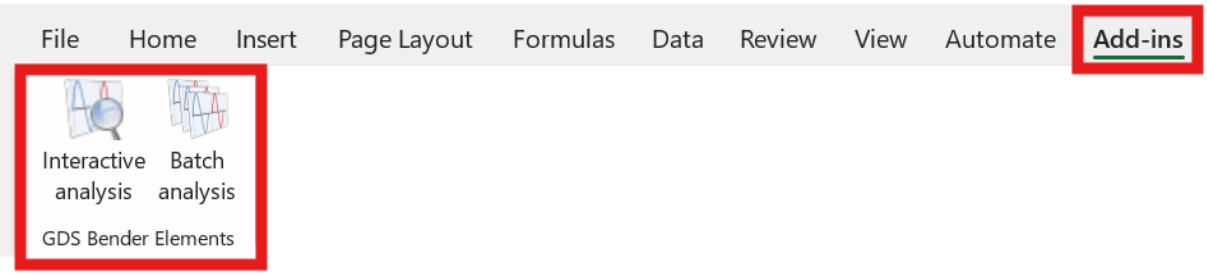
1.1 Download and Install the Tool

1. **Download the Tool**:
    - Visit the GDS Instruments website and download the GDS Bender Element Analysis Tool package.
2. **Run the Installer**:
    - Locate the setup package and double-click to run the installer.
    - Follow the on-screen instructions to complete the installation process.

1.2. Accessing the Tool in Excel

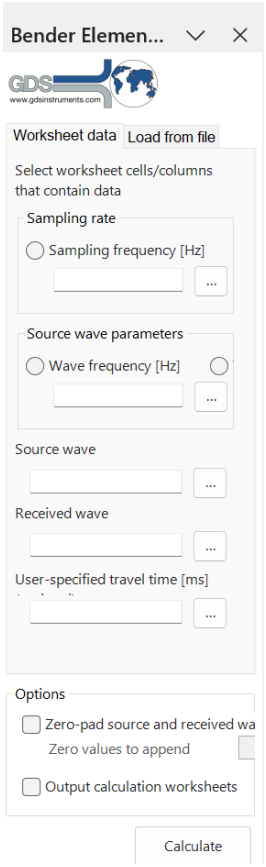
The tool integrates into Microsoft Excel as two add-ins:

- **Interactive Analysis**: For analysing single test data sets.
- **Batch Analysis**: For processing multiple test files formatted in the GDS.BES format.



1.3. Using the Interactive Analysis

To analyse a single data set:



1. Open Excel and click the **Interactive Analysis** button in the GDS menu.
2. A control panel will appear on the right-hand side of the screen.

1.3.1 Load Test Data

- Import your Bender Element Test data into an Excel worksheet.

1.3.2 Set Parameters

- **Sampling Rate**: Enter the sampling frequency or time stamp for the test data.
    - Example: Choose "Sampling Frequency" and input the value.
- **Source Wave Parameter**: Choose between wave frequency or wave period.
    - Example: Select "Wave Period" and input the value.
- **Source and Received Wave Outputs**: Select the relevant columns containing the source and received wave data.
- Optional Settings:
    - **User-Specified Travel Time**: Enter a previously determined travel time (optional).
    - **Zero Padding**: Enable zero-padding for source and received wave signals, if required.
    - **Output Worksheets**: Check this option to generate detailed calculation worksheets.

3. Click **Calculate** to begin the analysis.

1.3.3 Adjust Frequency Window

- After the initial analysis, refine the frequency domain analysis:
    - **Select a Frequency Range**: Adjust the range by interacting with the phase vs. frequency plot.
    - **Edit Numerically**: Input specific frequency limits directly.
- Click **OK** to update the analysis results.

1.4. Review the Results

Analysis results are displayed in two Excel tabs:

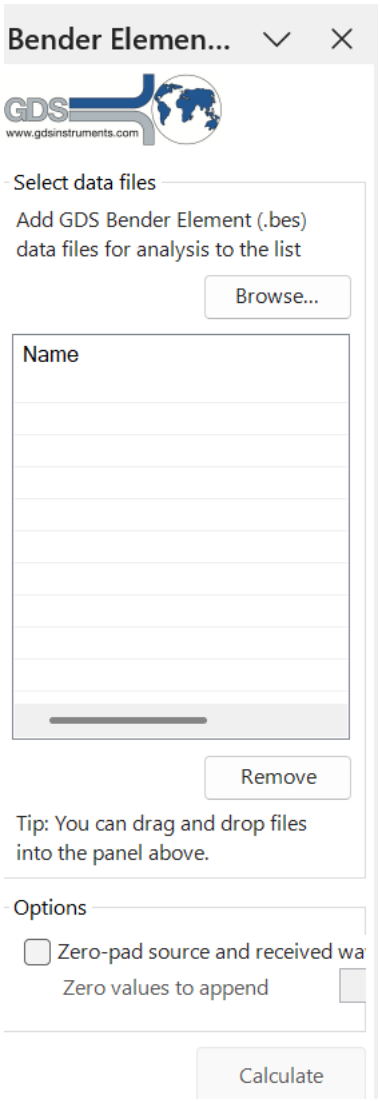
1.4.1 Travel Time Report Tab

- Contains numerical data, including:
    - File name of the test.
    - Estimated travel times from frequency and time domain analyses.
    - User-specified travel time (if provided).
    - Times of key points of interest in the received signal:
        - First deflection
        - First bump maximum
        - Zero crossing
        - Major first peak
    - Additional frequency diagnostics and sampling metrics.

1.4.2 Graphs Tab

- Provides visual representations, including:
    - Source and received wave outputs.
    - Travel time estimates (frequency and time domain analyses).
    - Frequency spectrum and phase vs. frequency plots.
    - Correlation values from time domain analysis.

1.5. Using the Batch Analysis



To analyse multiple test files:

1. Format files in the **GDS.BES** format.
2. Drag and drop the test files into the **Batch Analysis** window (accessible from the GDS menu in Excel).
3. Optional: Enable zero-padding for signals.
4. Click **Calculate** to start the batch analysis.
5. Results will populate the same **Travel Time Report** and **Graphs** tabs.

1.6. Key Features and Benefits

- **Objective Analysis**: Estimates travel times using frequency and time domain methods.
- **Compatibility**: Analyses data from any Bender Element Test system, not limited to GDS systems.
- **User-Friendly**: Requires no programming knowledge, integrating seamlessly into Excel.
- **Comprehensive Reporting**: Provides numerical and visual outputs to facilitate engineering judgment.

1.7. Notes and Recommendations

- The tool is provided to encourage discussion and refinement of shear wave travel time analysis standards.
- Always verify automated results with engineering judgment to ensure reliability.
- Refer to the accompanying documentation for additional guidance.

For further support, contact **GDS Instruments**.

2. FAQ's

2.1 General Questions

2.1.1 What is GDS BEAT?

The GDS Bender Element Analysis Tool (GDS BEAT) is a free-to-download set of Add-Ins for Microsoft Excel 2007, 2016, and later versions. It allows shear wave travel times to be estimated from bender element test data via automated analysis methods.

2.1.2 Why did GDS Instruments develop and share the tool?

The development of this tool has come about due to the subjectivity and current lack of satisfactory standards for interpreting shear wave travel times from Bender Element Test data. Using GDS Instruments' long-standing experience in providing systems to perform Bender Element Tests, we thought it worthwhile creating a simple-to-use tool.

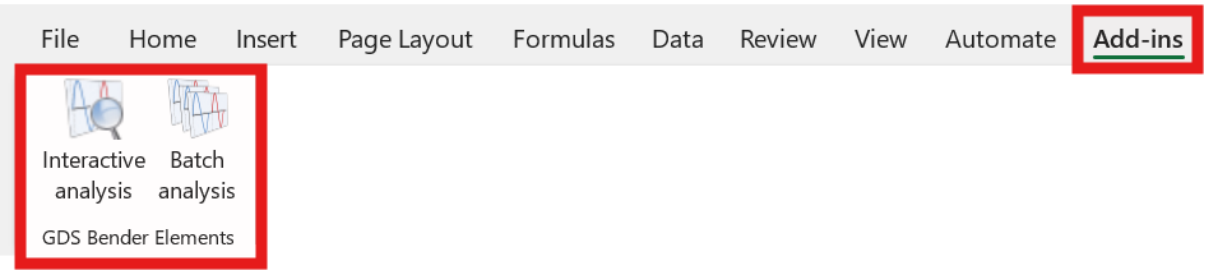
The aim is to share our software with the geotechnical community and help the progression towards accepted standards for these tests. We are happy for customers to distribute the tool but are reminded the purpose of the tool is to create discussion rather than consider this the final word in automated Bender Element Analysis. The tool itself is an easy-to-use set of add-ins accessible through Microsoft Excel, allowing any laboratory to participate in performing automated analyses of Bender Element Data without the prior requirement of software programming knowledge. Benefits of the tool include its ability to estimate travel times using both frequency and time domain analysis methods previously suggested in the geotechnical literature, and the flexibility to analyse data taken from any manufacturer's Bender Element Test system, not just GDS's. Reporting of the analysis is both numerical and visual, allowing the validity of the results to be quickly assessed as the tool still does require engineering judgement from the user.

2.1.3 Where can I obtain GDS BEAT?

The tool can be downloaded for free from the following address:
http://www.gdsinstruments.com/gds-products/free-download-bender-elements-analysis-tool

2.1.4 How do I start using GDS BEAT?

After downloading and installing GDS BEAT, open Microsoft Excel to access GDS BEAT through the Add-In tab. You can immediately start using the tool without the need for registration or activation.



2.1.5 Will GDS BEAT run on my operating system?

GDS BEAT can be installed and used on PCs running Windows XP SP3 or higher. Note Microsoft Excel 2007, 2016, or later must also be installed.

2.1.6 What are the terms of using GDS BEAT?

GDS BEAT is available free-of-charge, comes without warranty or technical support, and cannot be re-sold by a third party.

2.2 Analysis Methods Used

2.2.1 What methods does GDS BEAT use to estimate the shear wave travel times?

GDS BEAT primarily uses three common methods to estimate the shear wave travel times from bender element test data:

1. Observation of points of interest within the received element signal.
2. Cross-correlation of the source and received signals.
3. Cross-power spectrums of the source and received signals.

2.2.2 How does observation of the received signal work?

Observation of the received signal is designed to semi-automate the travel time estimation process often performed subjectively by the user. An algorithm within the tool attempts to identify the times at which key points occur, allowing the user to calculate travel times using methods such as ‘start-to-start’ or ‘peak-to-peak’.

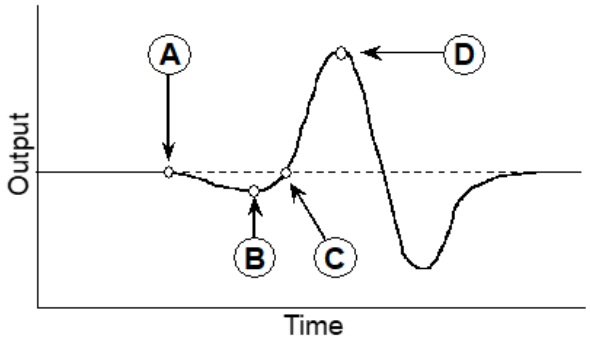


Figure 1 – Points of interest observed within the received element signal.

2.2.3 How does the cross-correlation work?

Cross-correlation values are calculated from the source and received element signals at each data time stamp. The time at which the maximum calculated cross-correlation value occurs is then used as an estimate of the shear wave travel time.

2.2.4 How does the cross-power spectrum calculation work?

The cross-power spectrums, obtained via a Fast Fourier Transform (FFT), are used to create a phase angle versus frequency plot. The slope of this plot is then used to estimate the shear wave travel time, based on a linear best fit across a defined frequency window. This frequency window can be adjusted by the user.

2.2.5 Where can I find more general information on these analysis methods?

The cross-correlation and cross-power spectrum methods have been widely used to estimate shear wave travel time for decades. Recommended references include:

- Viggiani, G. and J. H. Atkinson (1995). "Interpretation of bender element tests." Géotechnique 45(1): 149-154.
- Yamashita, S., et al. (2009). "Interpretation of international parallel test on the measurement of Gmax using bender elements." Soils and Foundations 49(4): 631-650.

2.3 Performing a Travel Time Analysis

2.3.1 When should I use the Interactive Analysis Add-In?

The Interactive Analysis Add-In is designed for use in analysing bender element test data taken from both GDS and non-GDS bender element systems. All parameters required to perform the analysis can be manually selected from data loaded into an Excel spreadsheet. It is also useful for altering the frequency window used in the cross-power spectrum analysis.

2.3.2 When should I use the Batch Analysis Add-In?

The Batch Analysis Add-In is designed for use in analysing multiple bender element tests primarily obtained from GDS systems. Users can reformat their test data into the GDS format (.bes) using the example data file provided on the GDS BEAT download page.

2.3.3 What does zero-padding the source and received element signals do?

Zero-padding adds a user-defined number of zeros to the end of both the source and received signals. This increases the number of discrete data points in each signal, allowing information to be reported at specific frequencies. It is recommended for advanced users familiar with spectral analyses. Further details can be found at: http://www.ni.com/white-paper/4880/en

2.3.4 What does checking the 'Output calculation worksheets' do?

Checking this box in the Interactive Analysis Add-In generates two additional tabs after analysis completion: 'Time domain calc' and 'Frequency domain calc'. These tabs provide detailed results for cross-correlation and cross-spectrum analyses. This feature is not available for the Batch Analysis Add-In.

2.4 Analysis Reporting

2.4.1 What are the 'Frequency domain diagnostics'?

These diagnostics provide numerical values of the frequency window used in the cross-spectrum analysis and the R^2 value of the linear best fit curve.

2.4.2 How are the 'Peak-peak freq' values listed in the source and received wave metrics determined?

The peak-peak frequencies are determined by:

1. Identifying the time between the peak and trough of each waveform.
2. Multiplying this time by a factor of two to estimate the waveform period.
3. Inverting the period to produce a frequency value.

2.4.3 How are the ‘Additional travel time estimations’ determined in the frequency domain analysis?

These are determined by calculating the slope of the phase angle versus frequency plot between specific frequency steps.

2.4.4 How are the ‘Additional travel time estimations’ determined in the time domain analysis?

Cross-correlation values are calculated using the received wave element signal and sinusoidal waveforms with frequency equal to the source and received ‘Peak-peak freq’ values.

2.4.5 Why do the bender element signals displayed in the ‘Graphs’ tab appear incomplete?

The graphs are down-sampled during processing to increase analysis speed. These outputs are intended for quick validation, not for detailed reporting.

3. References

- Viggiani, G. and J. H. Atkinson (1995). "Interpretation of bender element tests." Géotechnique 45(1): 149-154.
- Yamashita, S., et al. (2009). "Interpretation of international parallel test on the measurement of Gmax using bender elements." Soils and Foundations 49(4): 631-650.