Lamb vs. Air (LA) Ratio (Quality Control Tool)

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Seismic Approach to Quality Management of HMA

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SUMMARY

- Field data sets acquired on July 22, 2020, on a newly constructed asphalt pavement near Lund, Sweden, are processed and evaluated for various purposes. The data sets were collected by using the old system ("SYS-RYD-2019").
- Ten (10) randomly selected 48-channel records (out of several hundred ones) are used for the following purposes: **(1)** evaluation of overall quality of data first obtained on a new ("fresh") asphalt road that has the most homogeneous properties in stiffness (i.e., shear velocity, Vs) and thickness throughout entire survey area, **(2)** testing of various multichannel techniques previously developed that can alleviate adverse influence of air waves on the target analyses (i.e., Lamb and Impact Echo analyses), and **(3)** testing of several quality control parameters for a particular type of wave (e.g., air or Lamb waves) such as overall amplitude ("Amp"), arrival time in ms ["msT0 (ms)"], velocity [e.g., "Vair (m/s)"], and peak frequency ["Fpeak (kHz)"]. Each purpose is further elaborated below.
- **(1)** The overall data quality is evaluated as "excellent" from raw field records and corresponding dispersion images that clearly show well-developed Lamb wave arrivals and the fundamental-mode anti-symmetric Lamb dispersion (A0), respectively.
- **(2)** Three previously developed techniques are tested to these ten (10) records that can alleviate the air-wave energy as much as possible without compromising other useful attributes of obtained wavefields [e.g., wavefields for Lamb and Impact Echo (IE) analyses].   They are surgical mute (MUTE), fk-filter (FK), and air-wave subtraction by using moving-window LMO stack (AIR-SUBTRACTED).
- **(3)** These four parameters ["Amp", "msT0 (m/s)", "V* (m/s)", and "Fpeak (kHz)"] will be evaluated against each raw record right after its acquisition to determine whether it meets minimum conditions for in-field analysis without compromising the overall reliability of the results [i.e., velocity (Vs) and thickness (H) of HMA layer]. If deemed not meeting the conditions, then it is not used for the in-field analysis and logged as "tossed-out record" in the in-field analysis log file.

(1) Evaluation of Overall Data Quality

This is the record #9 in field record (left) and corresponding dispersion image and other spectral characteristics (right). An approximate inversion results show velocity (Vs = 1400 m/), thickness (H = 0.1 m), and Poisson's ratio (POS = 0.3) (bottom). These are the results sent from Norrfee Tech.
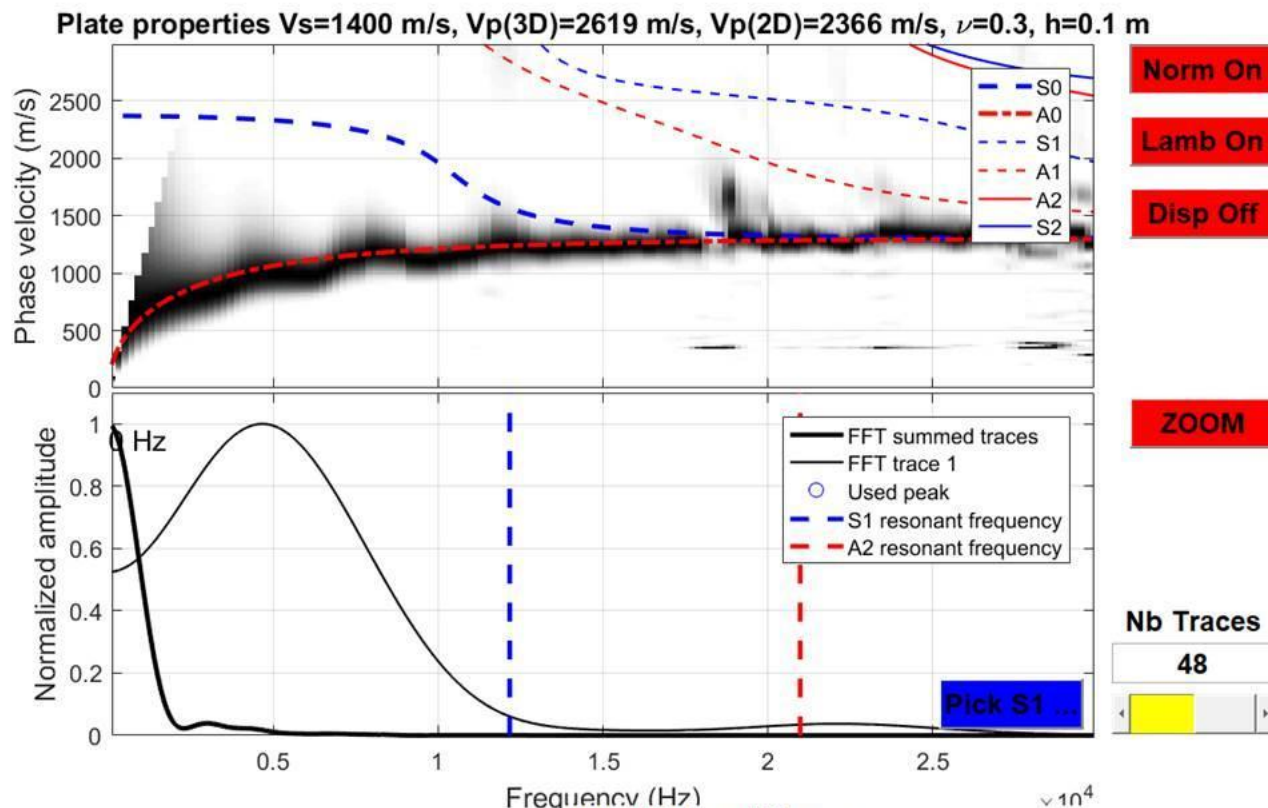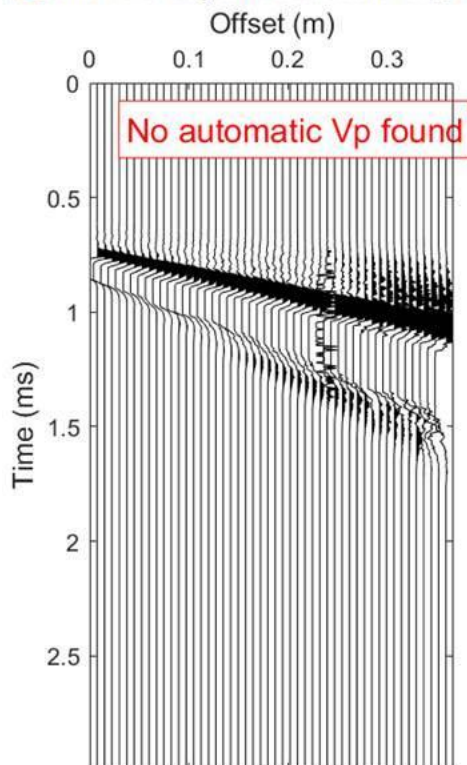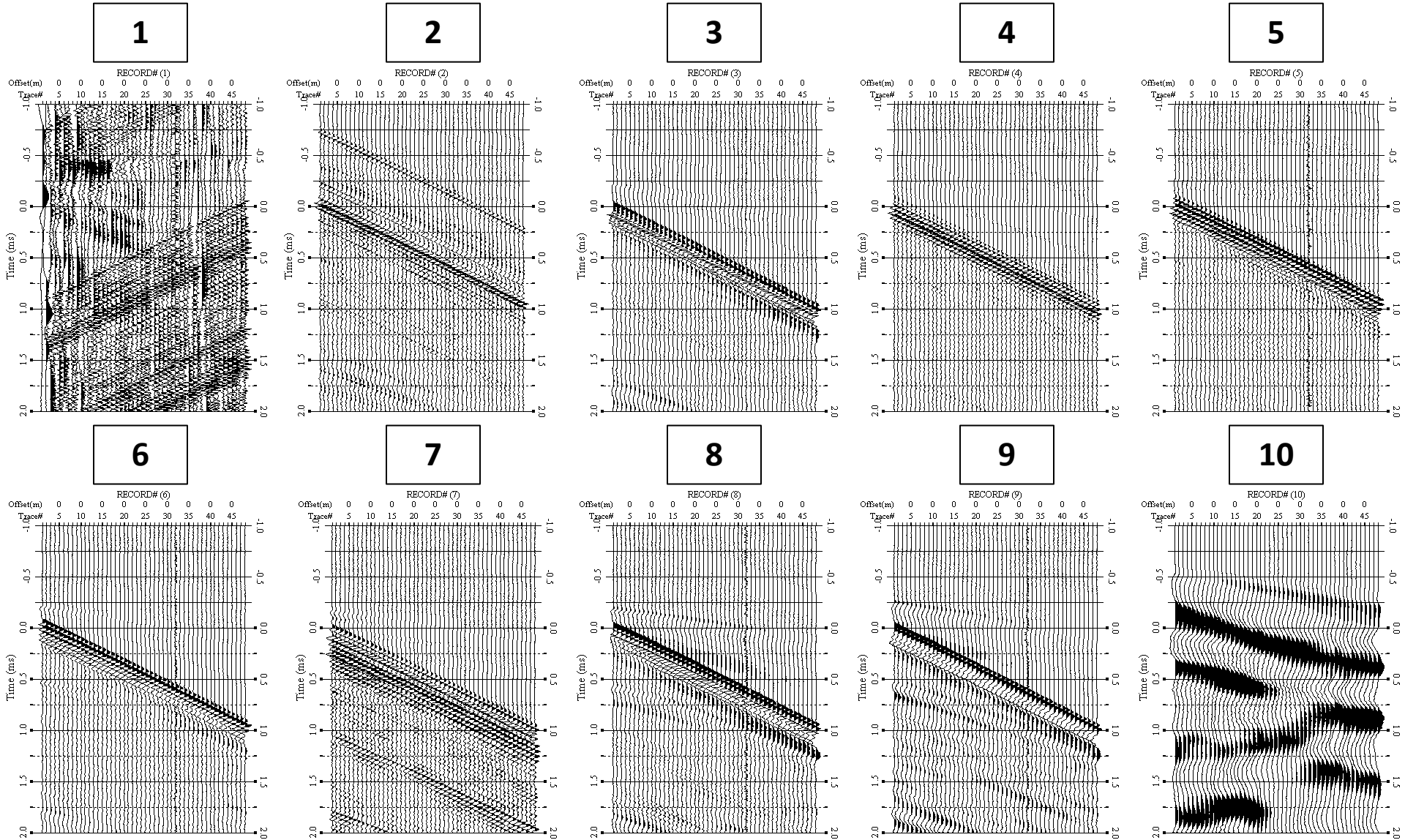
(2) Various Multichannel Techniques to Alleviate Air-Wave Influence

- Three previously tested/developed techniques are tested to these ten (10) records that can alleviate the air-wave energy as much as possible without compromising other useful attributes of obtained wavefields [e.g., wavefields for Lamb and Impact Echo (IE) analyses]. **They are surgical mute (MUTE), fk-filter (FK), and air-wave subtraction by using moving-window LMO stack (AIR-SUBTRACTED).**

RAW DATA

Only various types of air waves are visible. They are mostly consistent, but some are not (e.g., 1, 7, and 10).

AIR-WAVE MUTED DATA

After muting the portion of air waves and later arrivals, mostly lamb waves are visible. Fk filter was also applied to some record (e.g., 2)

AIR-WAVE FK'd DATA

Air waves are fk'd by using a narrow cut-velocity band (e.g., 300 m/s – 400 m/s). Both Lamb and remnant air waves are visible.

AIR-WAVE SUBTRACTED DATA

Air waves are subtracted by using [the moving-window LMO stack approach](). Both Lamb and remnant air waves are visible.
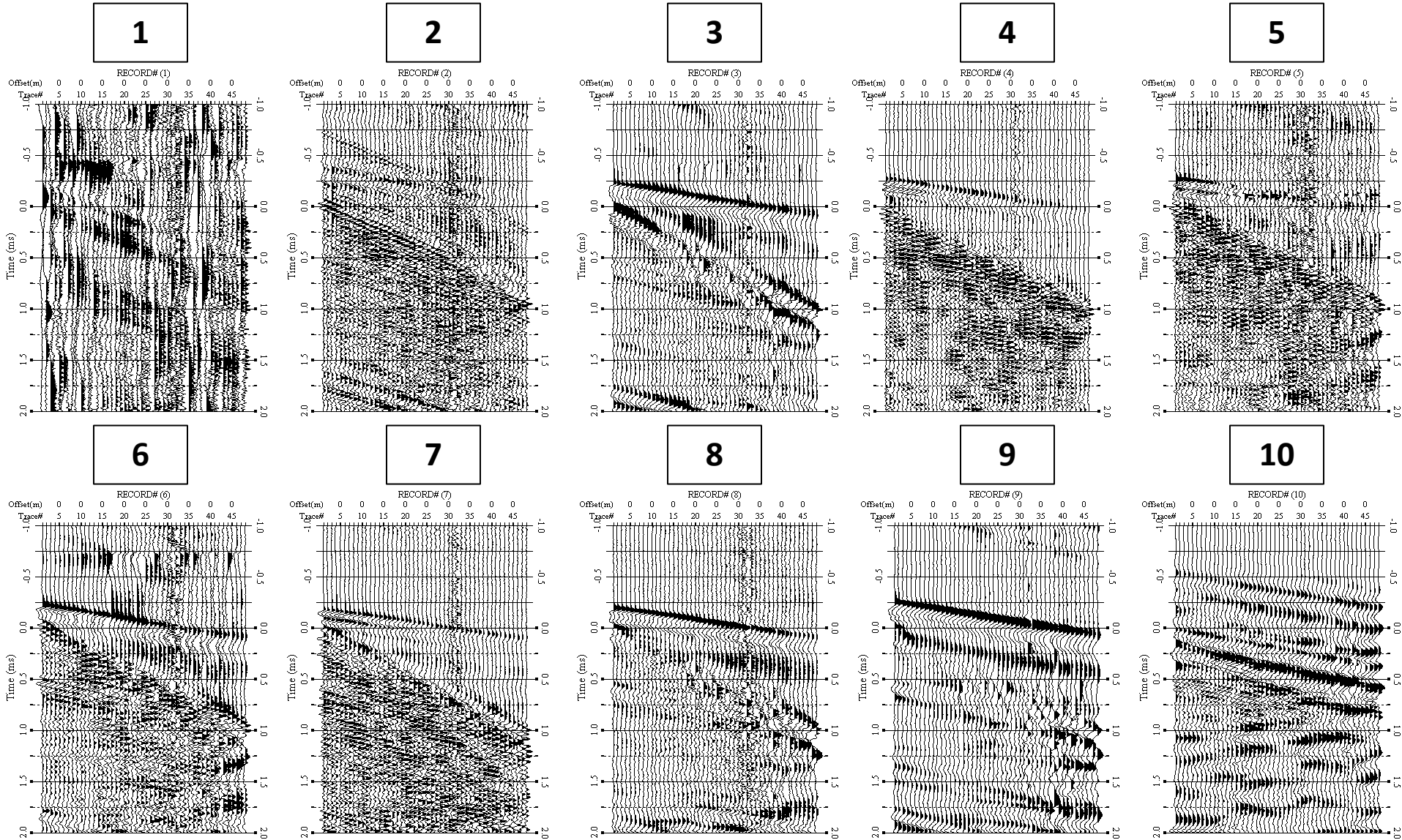
DISPERSION | RAW DATA

Mostly air waves are visible except for 10 that shows some low-frequency (e.g., < 10 kHz) Lamb waves.
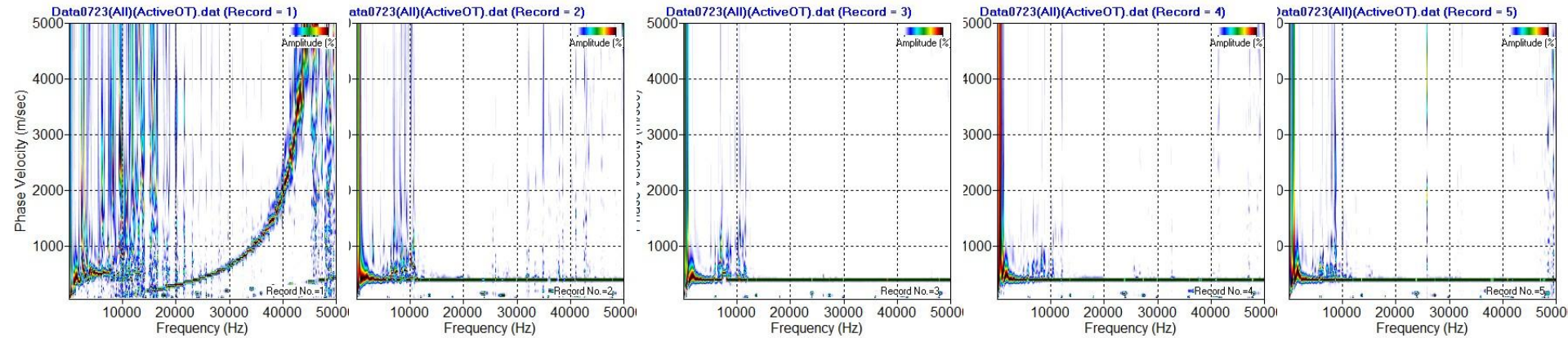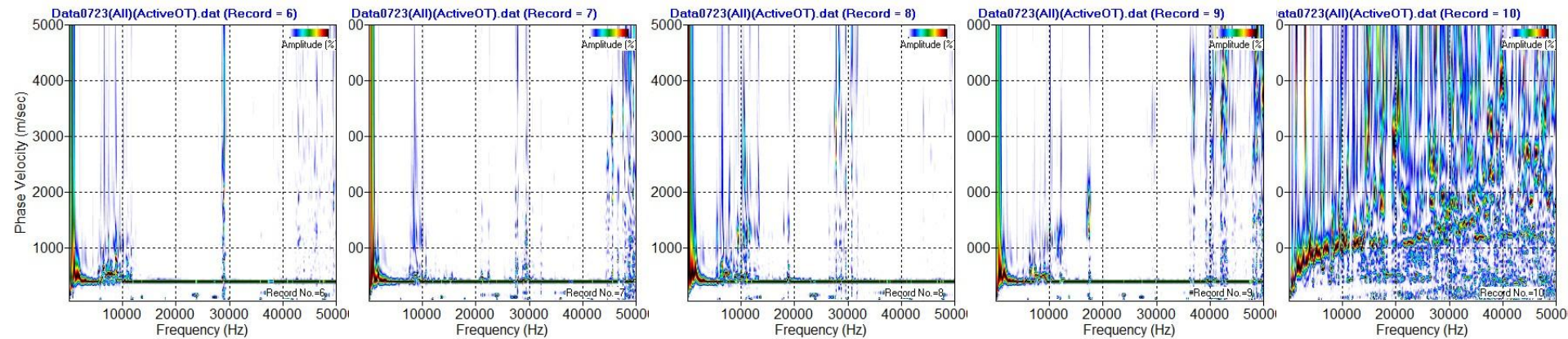
DISPERSION | AIR-WAVE MUTED DATA

Mostly Lamb waves are visible except for 1, 5, and 10.
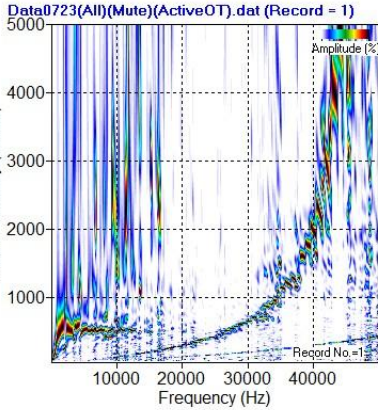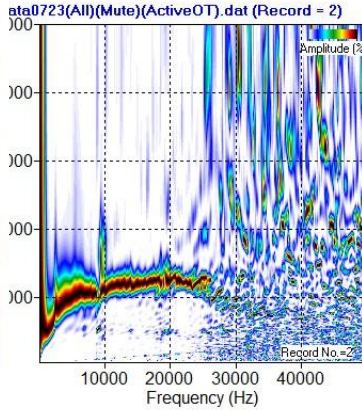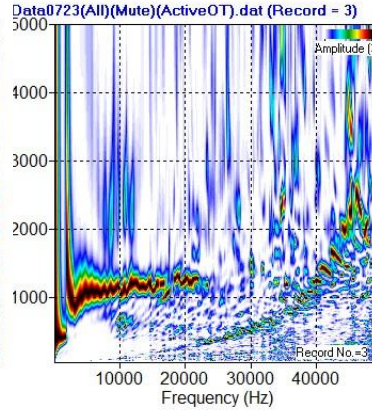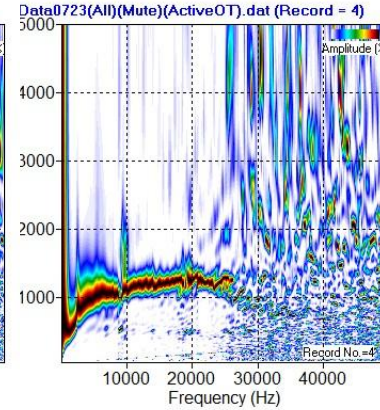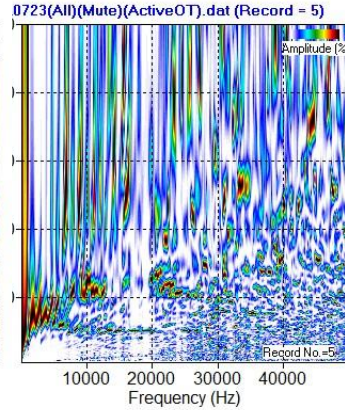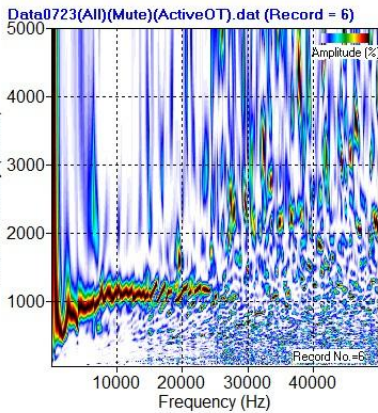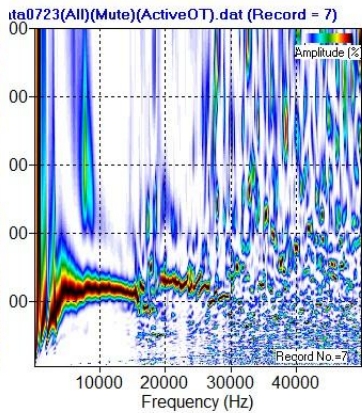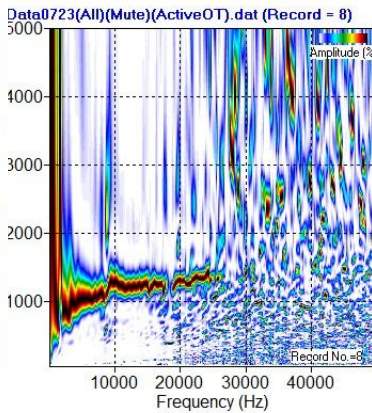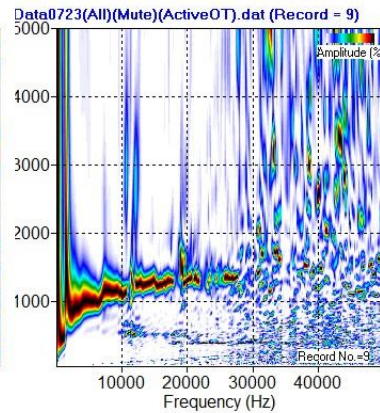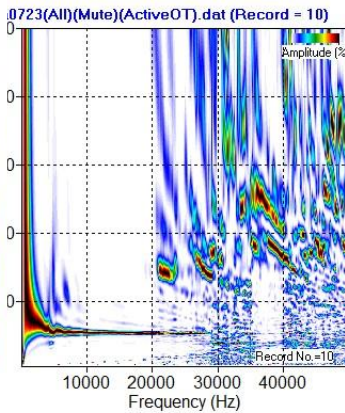
DISPERSION | AIR-WAVE FK'd DATA

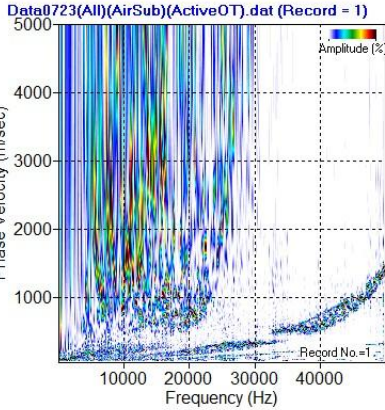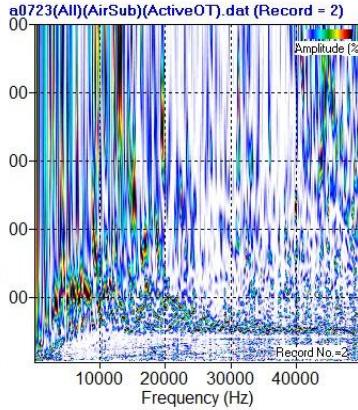**Mostly low-frequency Lamb waves are visible. In general, the overall quality is not good.**
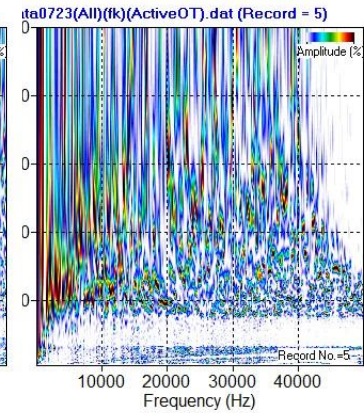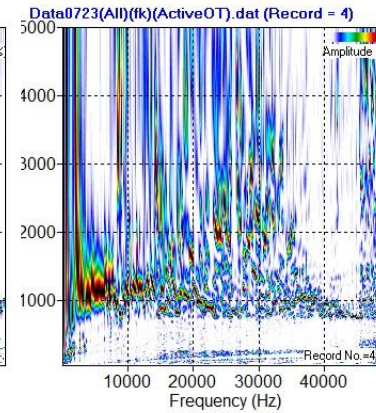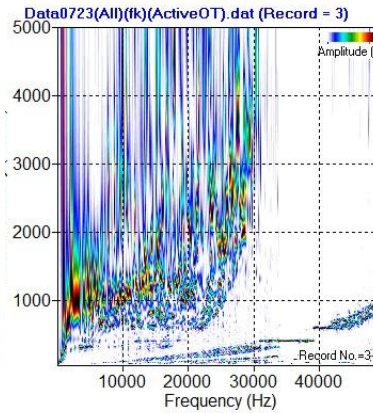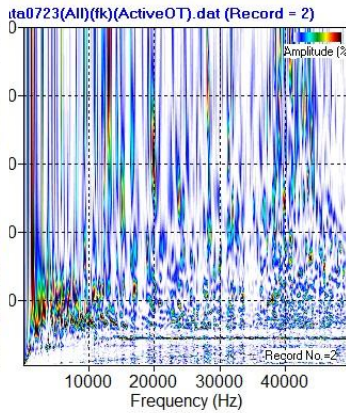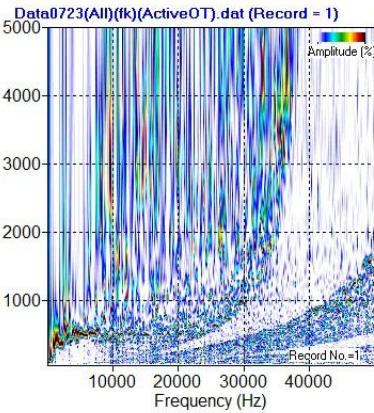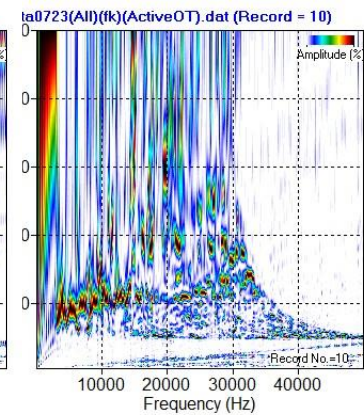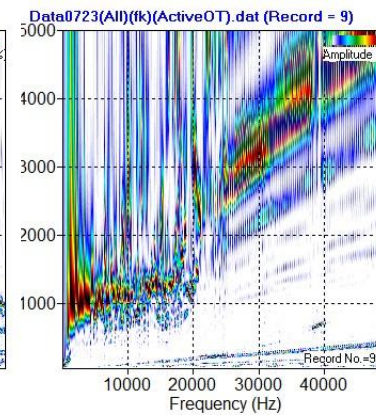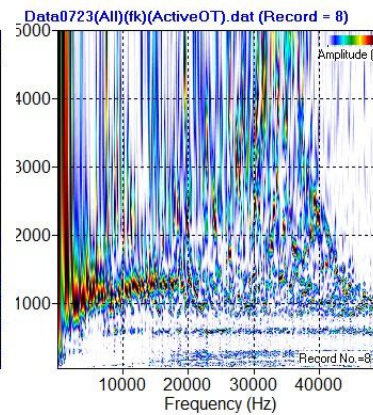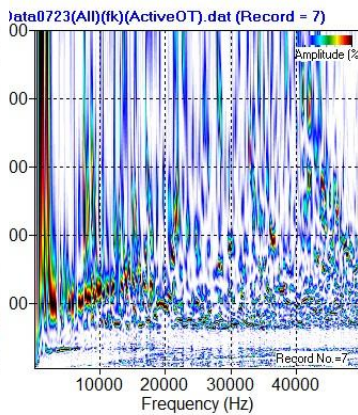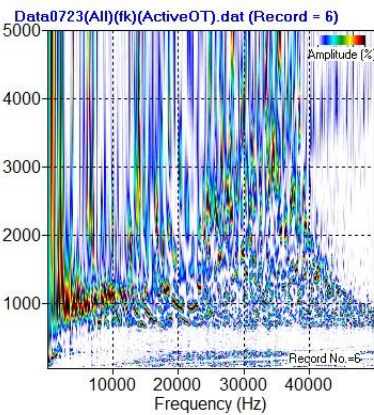
DISPERSION | AIR-WAVE SUBTRACTED DATA

In general, the overall quality is similar to that of the FK'd data with a slight improvement.
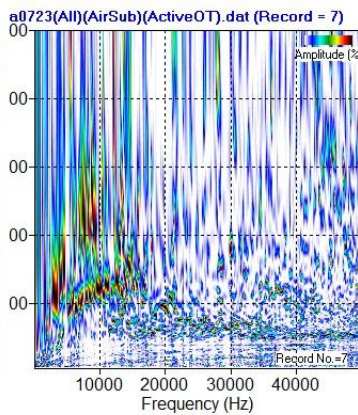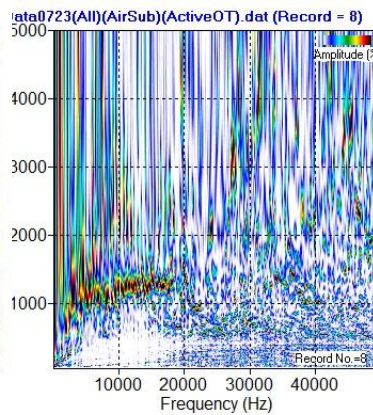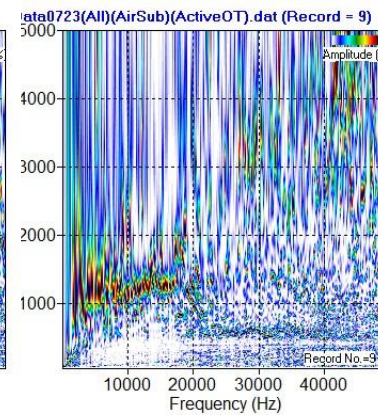
MUTE
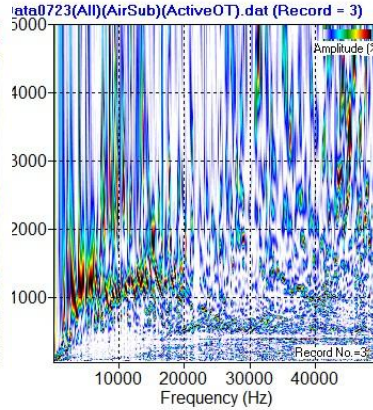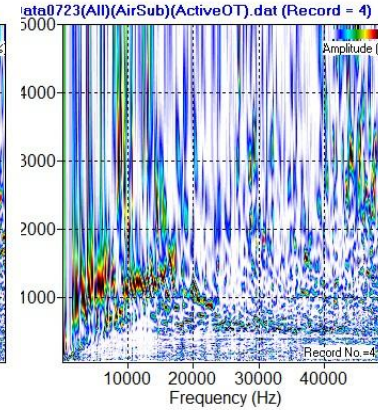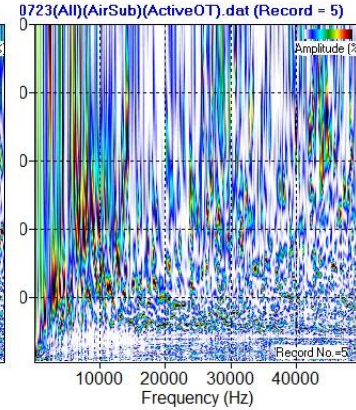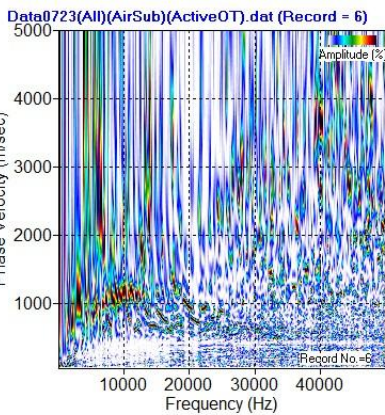
This shows that a sequence of muting air waves and subsequent later arrivals and then pre-Lamb arrivals progressively improves the quality of dispersion image.
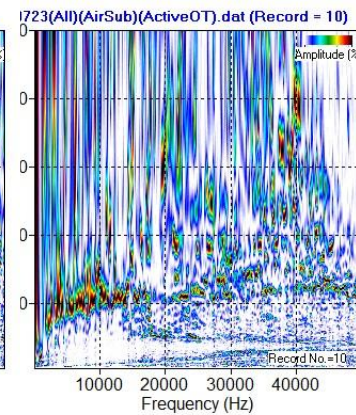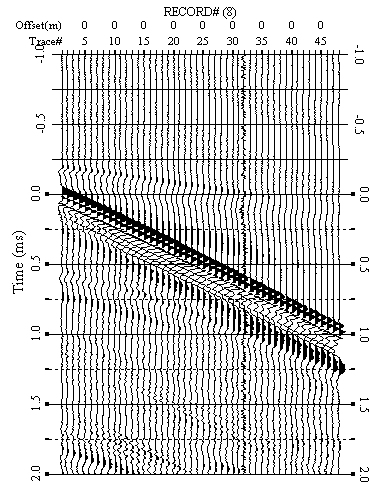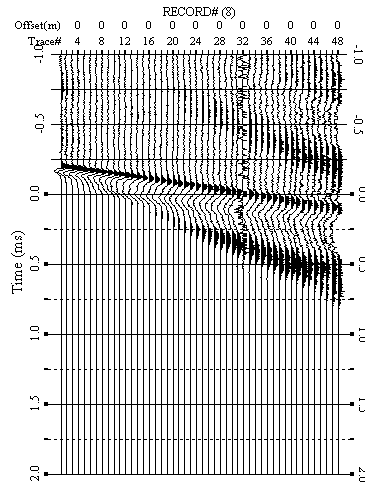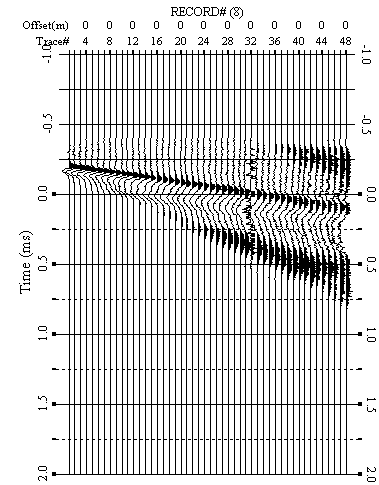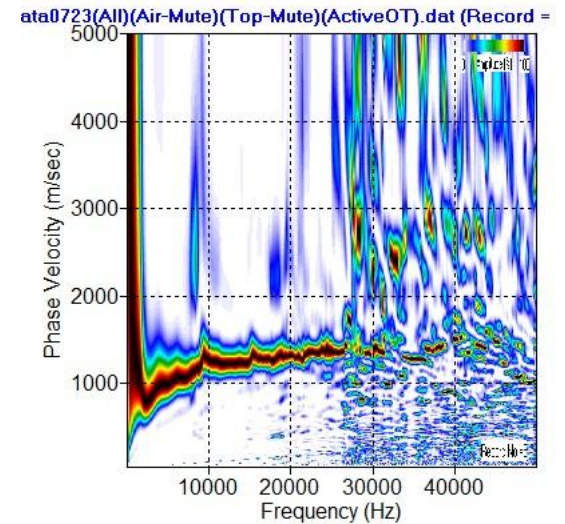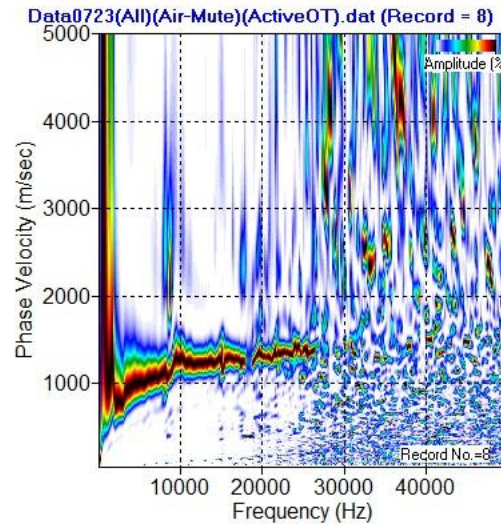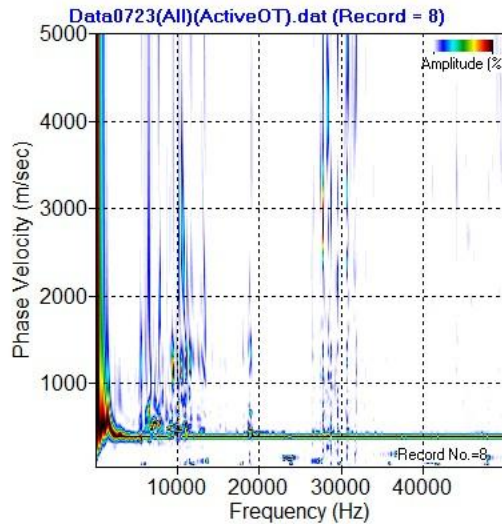
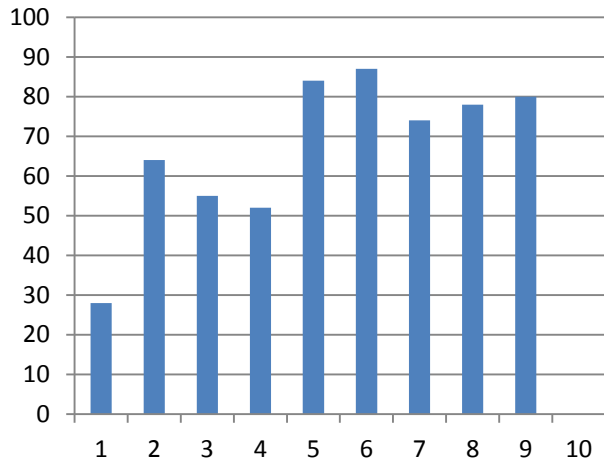

| RAW | AIR MUTE | AIR + TOP MUTE |

(3) Testing of Several Quality Control (QC) Parameters

- Several quality control parameters for a particular type of wave (e.g., air or Lamb waves) such as overall amplitude ("**Amp**"), arrival time in ms ["msT0 (ms)"], velocity [e.g., "**Vair (m/s)**"], and peak frequency ["**Fpeak (kHz)**"] are tested.

- These four parameters will be evaluated against each raw record right after its acquisition to determine **whether it meets minimum conditions for in-field analysis without compromising the overall reliability of the results** [i.e., velocity (Vs) and thickness (H) of HMA layer]. If deemed not meeting the conditions, then it is not used for in-field analysis and logged as "**tossed-out record**" in the in-field analysis log file.

LMO Stack of Field Record

This shows how Lamb and air waves are distinguished in velocity and arrival time, which are important properties in inventing schemes to evaluate both type of waves for quality control purposes.
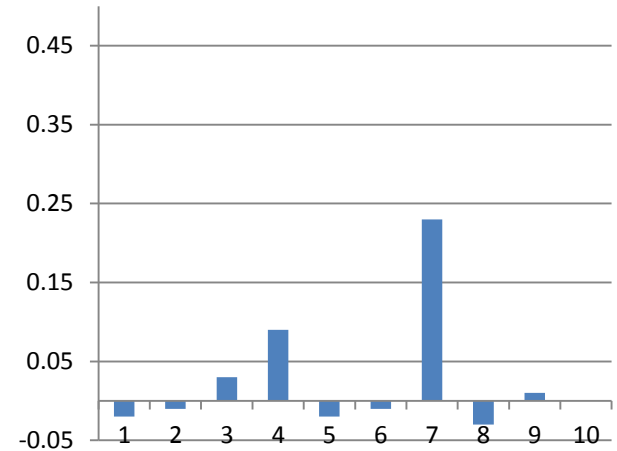
Field Record (#8)
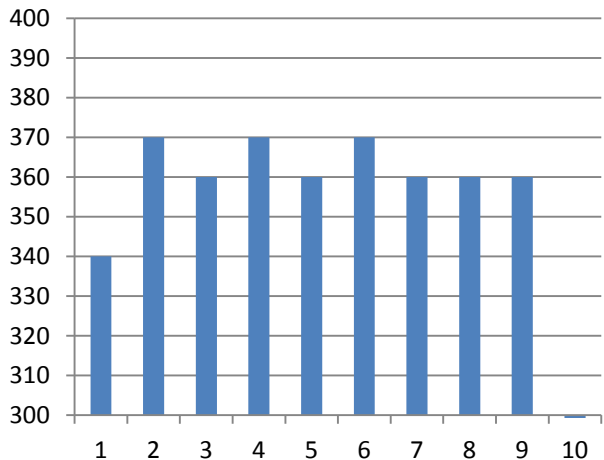
LMO Stack

DETECT AIR WAVE ATTRIBUTES

Amp (%)

Attributes of air waves are measured and displayed by bar graphs here. They are amplitude (Amp), arrival time in ms [msT0 (ms)], velocity [Vair (m/s), and peak frequency [Fpeak (kHz)]. If there is no peak in LMO stack within a specified testing range of velocity (e.g., 300 m/s – 400 m/s), then the amplitude is set to be zero (0) and all other attributes are also set to be zeros (0's).
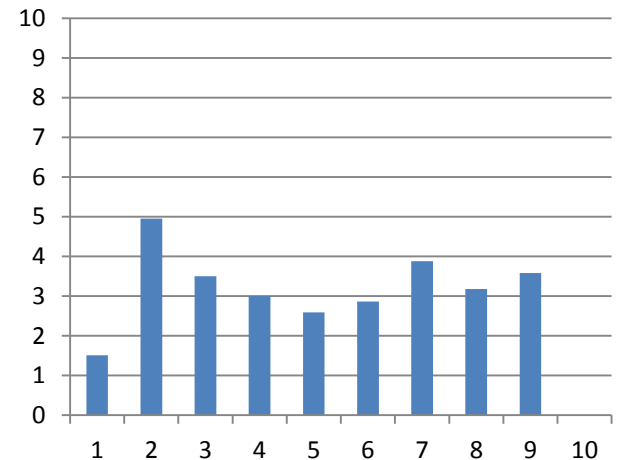
msT0 (ms)


Vair (m/s)

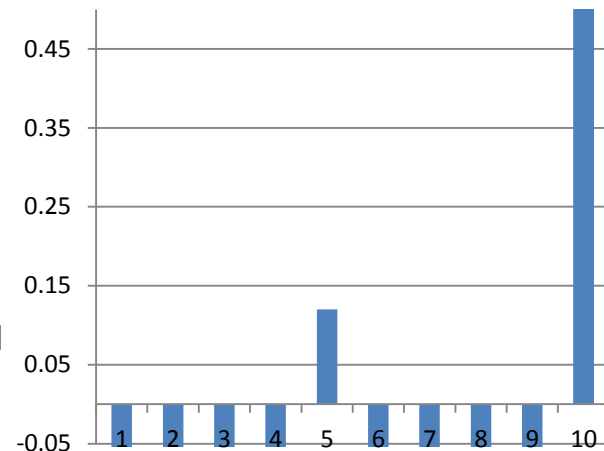## Fpeak (kHz)

DETECT LAMB WAVE ATTRIBUTES

Attributes of Lamb waves are measured and displayed by bar graphs here. They are amplitude (Lamb-Amp), arrival time in ms [msT0 (ms)], velocity [Vlamb (m/s), and peak frequency [Fpeak (kHz)]. If there is no peak in LMO stack within a specified range of testing velocity (e.g., 700 m/s – 3000 m/s), then the amplitude is set to be zero (0) and all other attributes are also set to be zeros (0's).

After muting air waves, the Lamb amplitudes (Lamb-Amp) are re-evaluated to get the L/A Ratio. If Lamb-Amp in this case is lower than a certain value (e.g., 0.3), L/A is set to be zero (0).
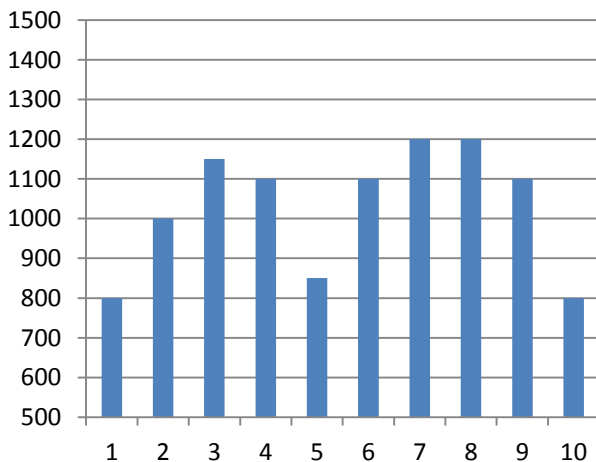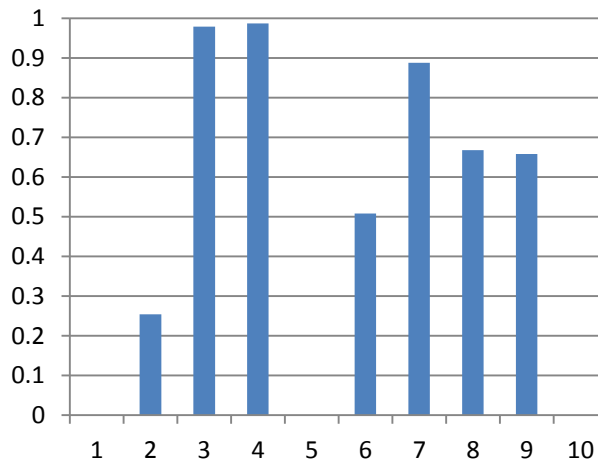
Lamb-Amp (%)
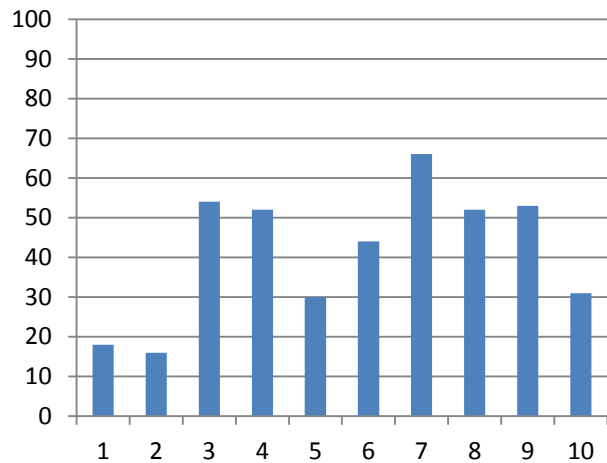
msT0 (ms)

Vlamb (m/s)

L/A Ratio

Fpeak (kHz)