Air Wave Attenuation Through Software Approaches

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Seismic Approach to Quality Management of HMA

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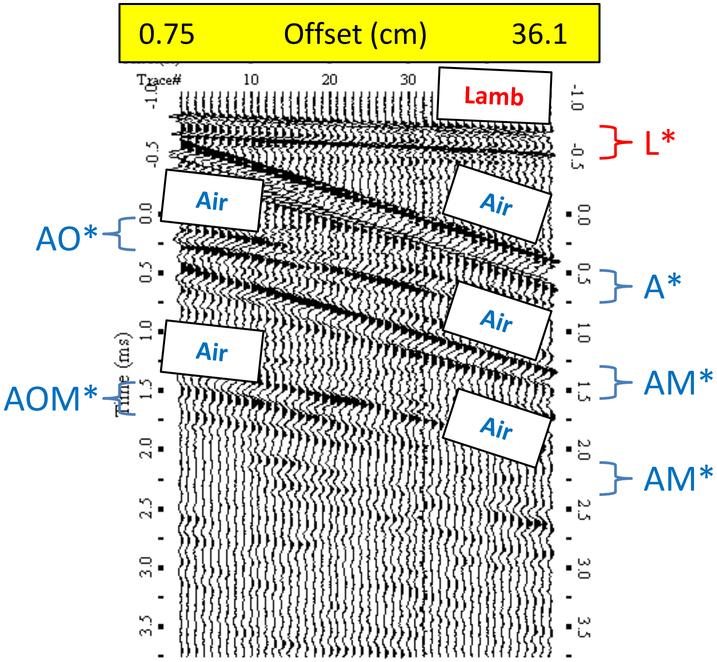
SUMMARY

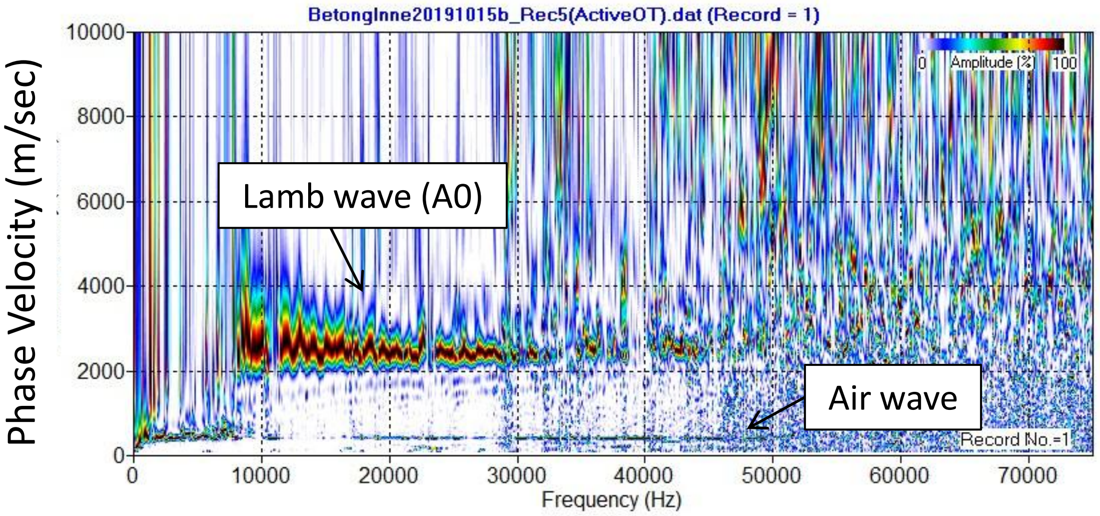
- Direct air (sound) waves generated at and coming from the impact point are the most troublesome noise for the microphone measurement of leaky-mode Lamb waves that have to be suppressed by means of both acquisition and post-acquisition efforts.
- This type of wave ("air wave") is very strong in comparison to the signal Lamb waves that can saturate the available dynamic range of an acquisition system.
- Considering its significantly lower velocity (e.g., 345 m/s) than typical Lamb wave velocity (e.g., 1500 m/s), it could be controlled through "optimum time-window" approach by delaying its arrival time as much as possible.
- For this approach, however, the distance (X1) between seismic impact point and receivers should be long enough (e.g., ≥ 1 m) to warrant a sufficient amount of arrival time difference (e.g., ≥ 5 ms). This is not a practical option because X1 has to be as much small as possible (e.g., ≤ 0.2 m) to account for the rapid attenuation of Lamb waves in the asphalt pavement.
- Therefore, both types (Lamb and air waves) usually arrive within the earliest 2.0-ms window in a typical 10-ms record. It is inevitable to include both types in subsequent analysis steps to calculate the velocity (Vs) and thickness (H) of HMA pavement layer.
- Inclusion of air wave in the measurement can result in following adverse effects; (1) it may consume a given dynamic range of AD conversion that can result in a relatively low resolution available for low-energy Lamb waves at high frequencies (e.g., > 15 kHz), (2) this poorly-resolved high frequency components of Lamb wave can result in a less-reliable evaluation of seismic velocity (Vs), and (3) strong air waves at relatively low frequencies (e.g., < 10 kHz) can mask the "curved" part of the Lamb wave dispersion (A0) that is critical to accurately evaluate the thickness (H) of pavement.
- Here, the software approaches (i.e., the data-process approaches) are presented that can alleviate these harmful effects. A possible data-acquisition effort was previously discussed and presented [here](#).

Signal (Lamb) and Noise (Air) Waves

Full 48-Channel Record
(dx+ = 0.75 cm)



Dispersion Image

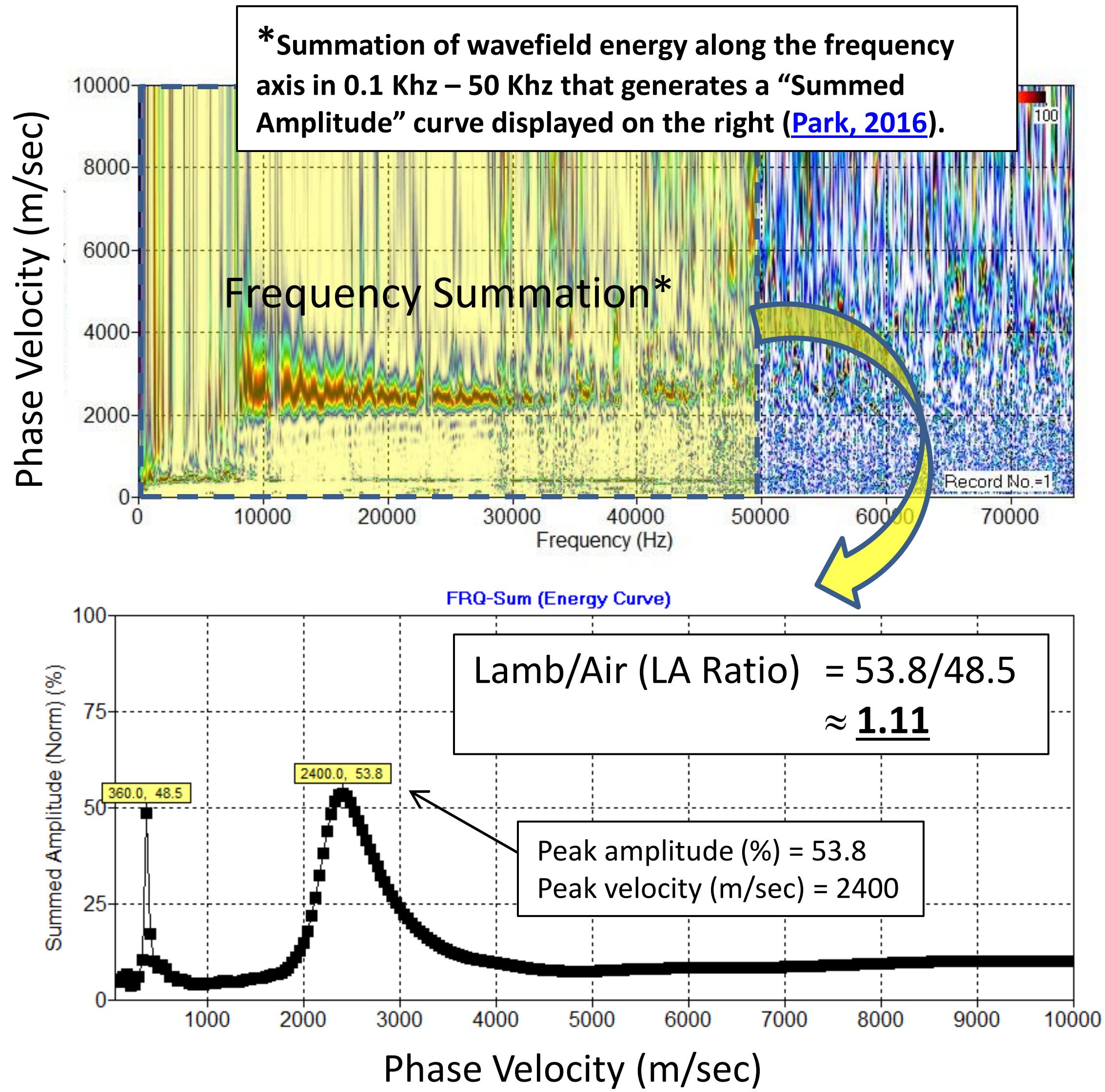


+MEMS microphone spacing.

L = Lamb wave, A = direct air wave, AM = air wave multiples from array bar, AO=air wave off-line reflection from the array-holding frame, AOM=multiple refection of AO.

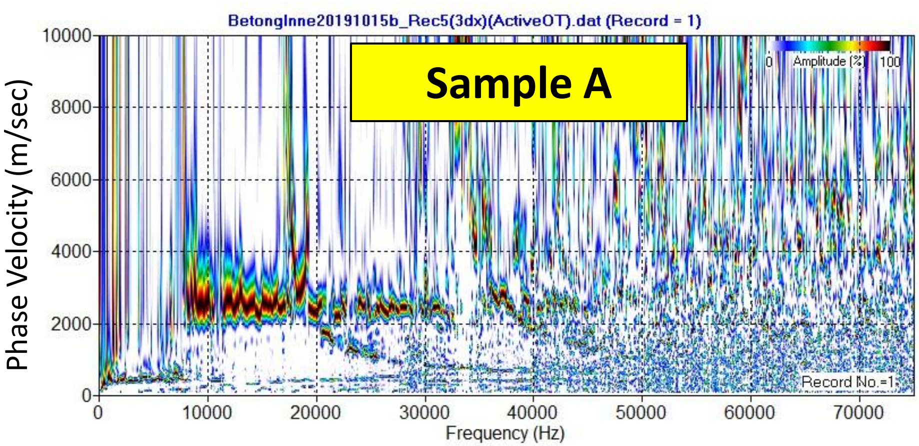
Evaluation of Lamb vs. Air Wave Energy (LA Ratio)

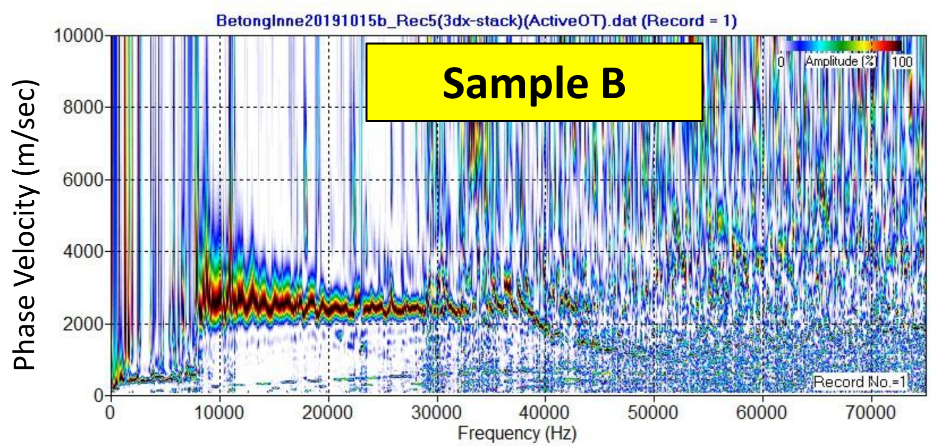
Asymptotic phase velocity of Lamb dispersion pattern (A0) is determined by the frequency summation method as illustrated on the right (Park, 2016). The value of phase velocity (Vph) where the peak amplitude occurs represents the surface wave velocity of pavement layer, which is 91% of its shear-wave velocity (Vs); i.e., Vph = 0.91xVs. The peak amplitude represents overall energy of the Lamb wave, which is directly related to the reliability of the evaluation. In general, a peak amplitude greater than 25% is considered reliable. The lower-frequency part of the A0 trend (e.g., < 9 kHz) is not visible due to the strong domination of air wave energy at the corresponding frequency range. Therefore, the overall ratio between Lamb and air wave energy (LA ratio) is the same concept as the signal-to-noise (SN) ratio that is often used to evaluate the reliability of an outcome from a certain data analysis step. A higher LA ratio means an enhanced reliability.

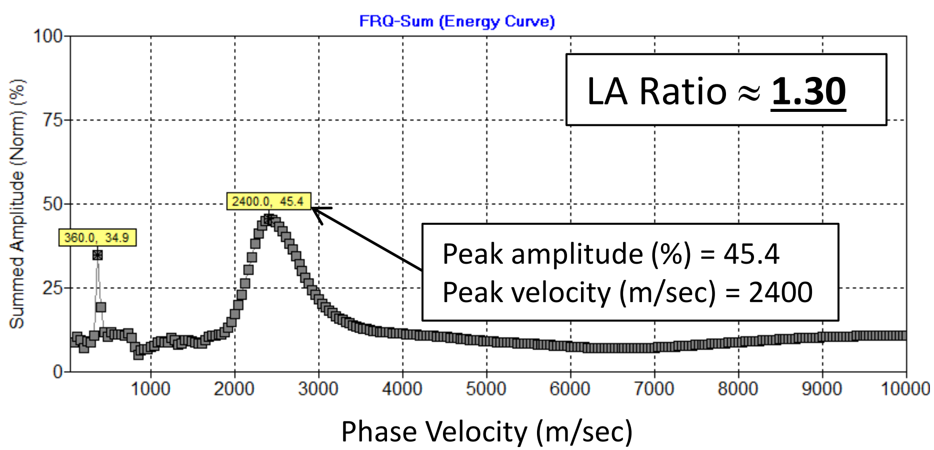


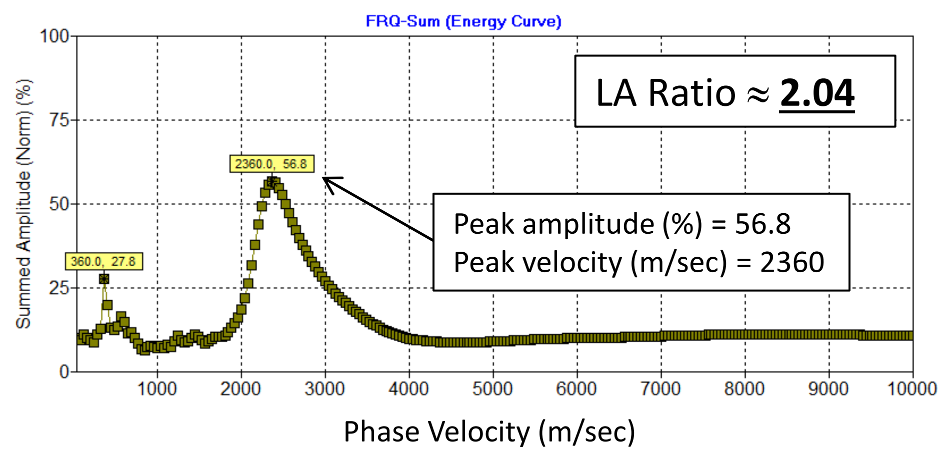
Samples of Different Peak Amplitudes and LA Ratios

Two samples are compared in the reliability of evaluated Lamb wave phase velocity (Vph). One (left) has a lower LA ratio of 1.30 with an evaluated Vph=2400 m/s, while the other (right) has a higher LA ratio of 2.04 with Vph=2360 m/s. Because of the higher LA ratio, the latter value (2360 m/s) is more reliable.





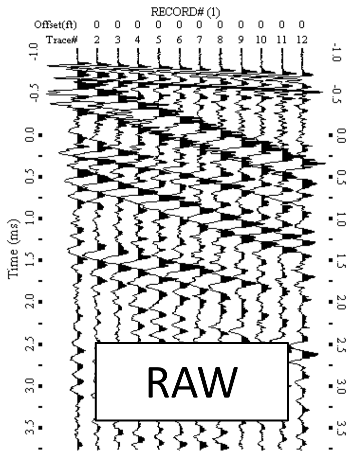


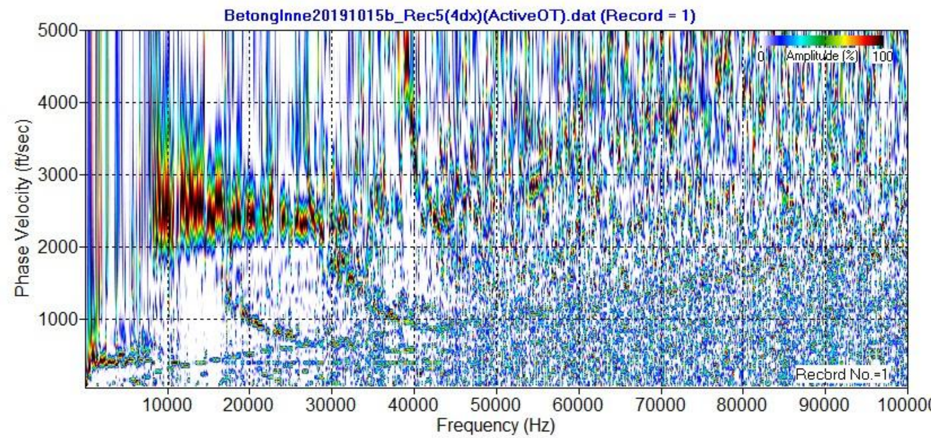


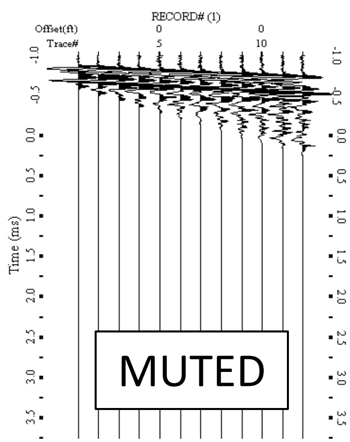
RAW and Muted (12-Channel) Record

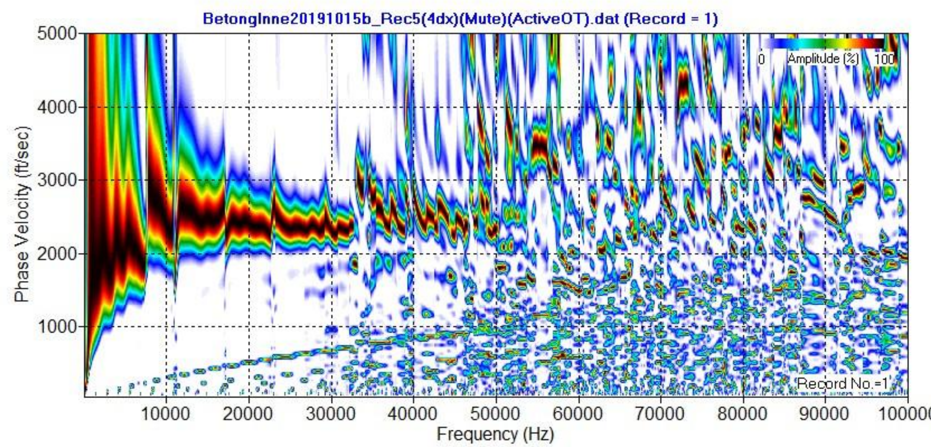
Field Record (12-Channel)

Dispersion Image









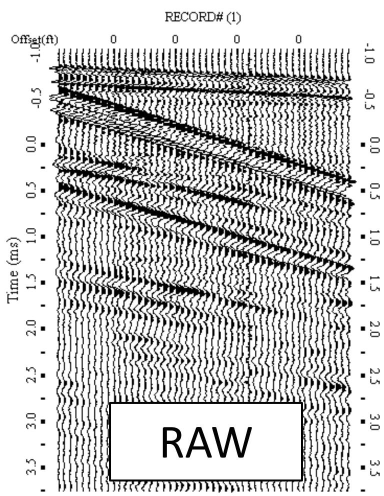
RAW and FK* (48-Channel) Record (dx⁺ = 0.75 cm)

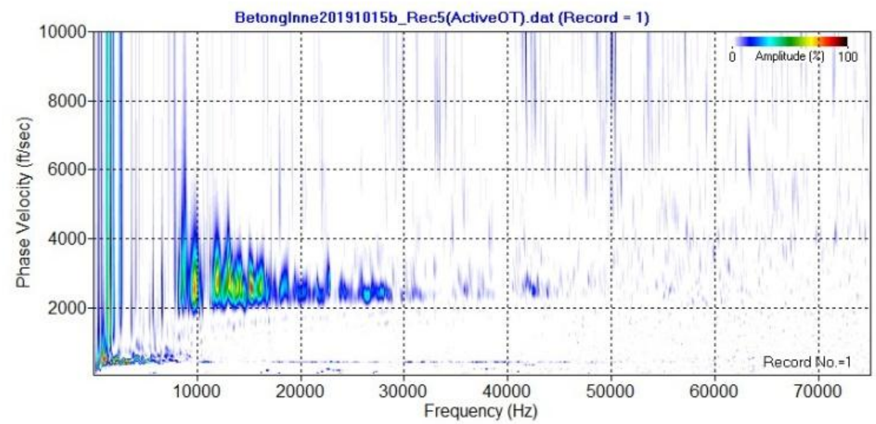
Field Record (48-Channel)

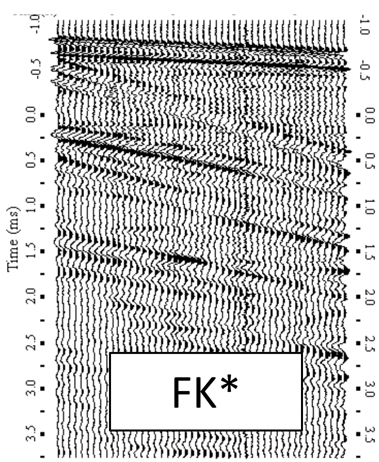
Dispersion Image

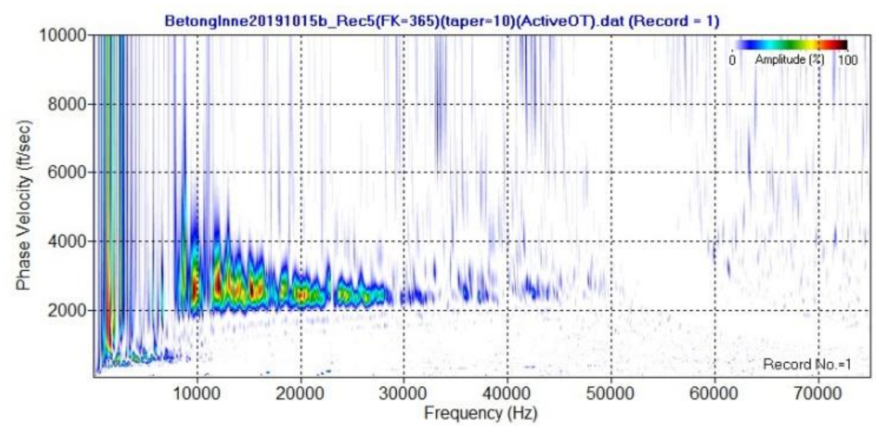
**FK filtered with a constant velocity of 365 m/s.*

⁺MEMS microphone spacing.

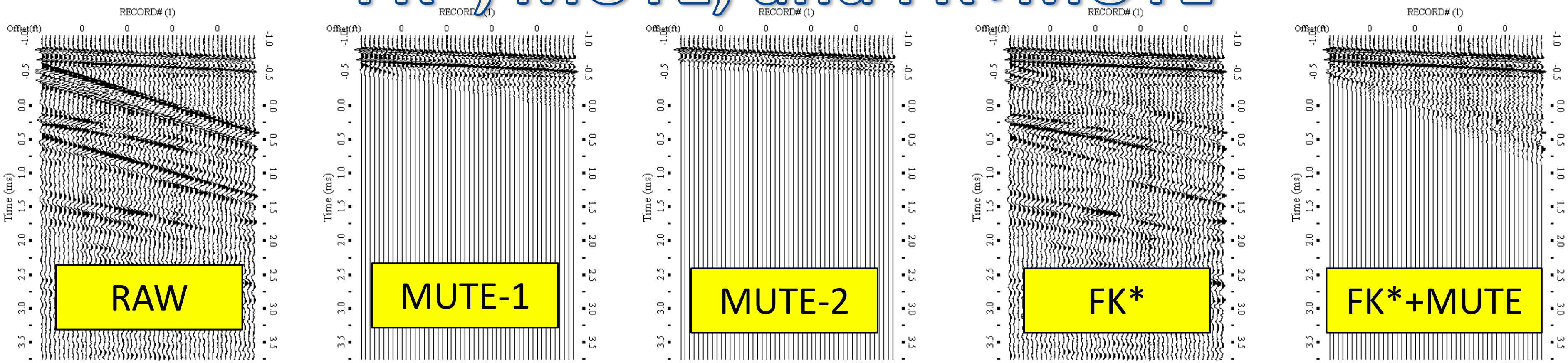


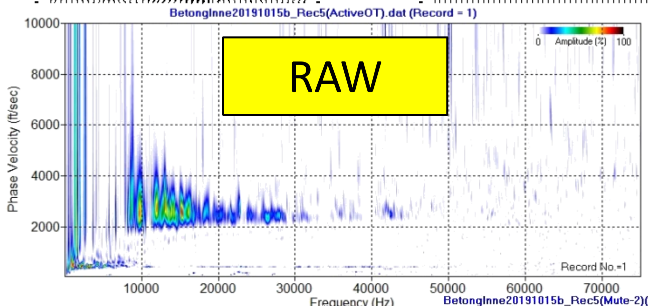




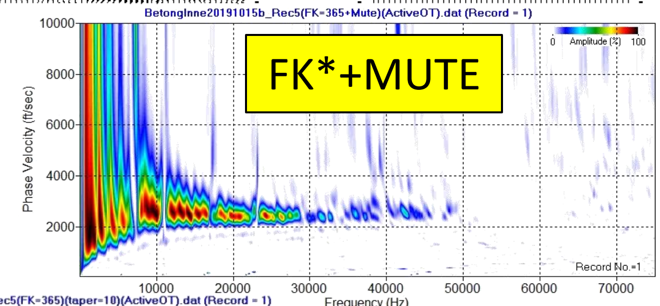


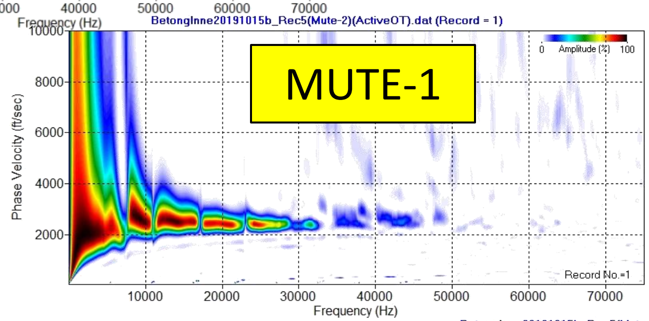
FK*, MUTE, and FK+MUTE

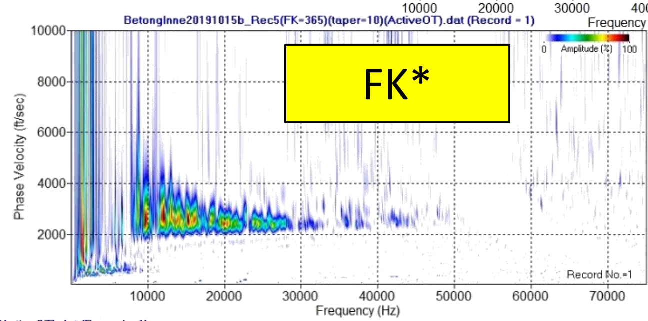


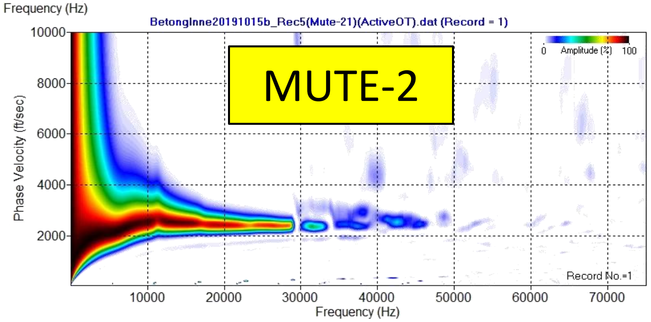


**FK filtered with a constant velocity of 365 m/s.*



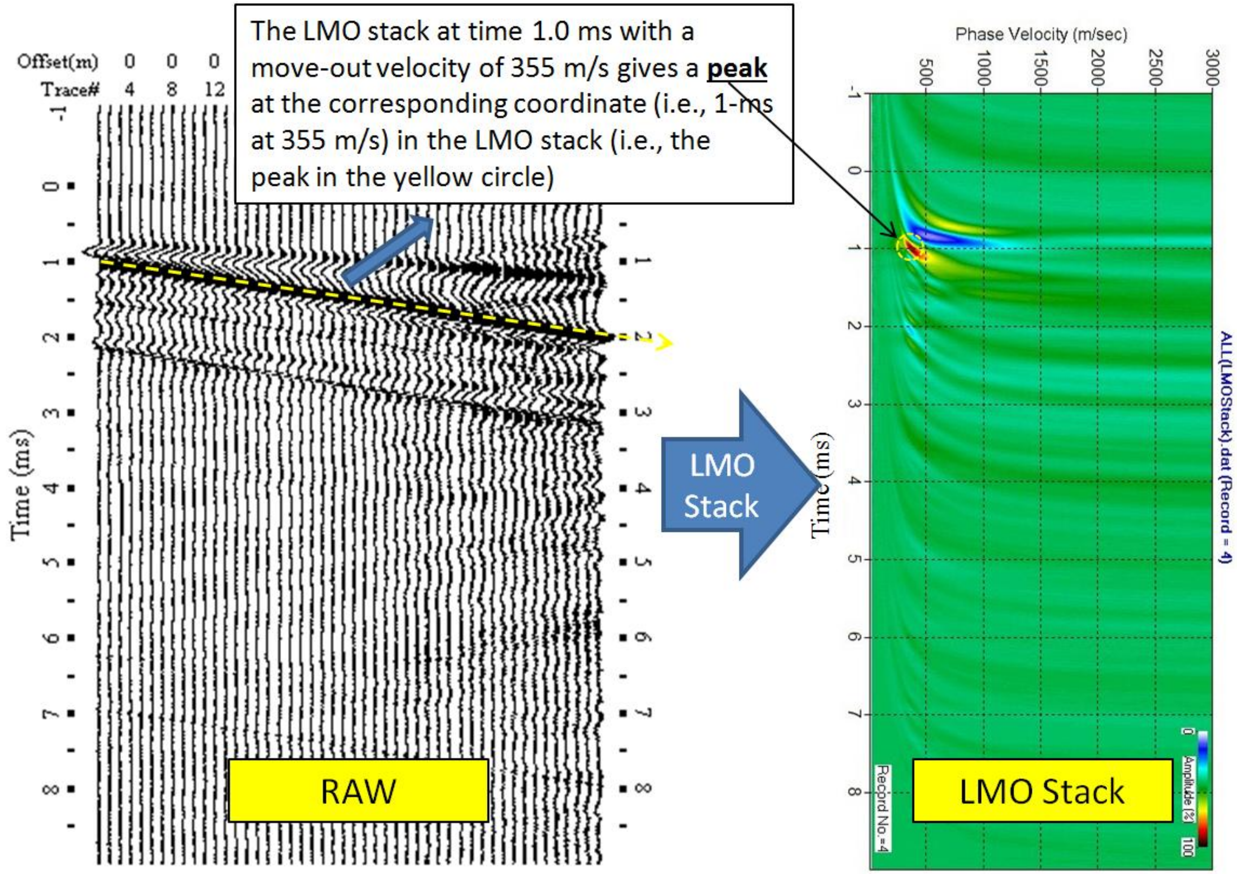






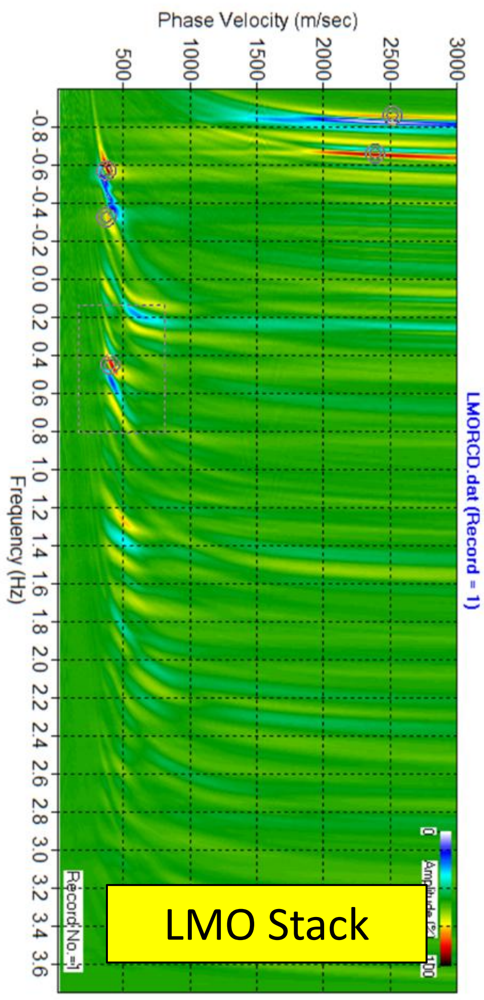
Linear Move Out (LMO) Stack

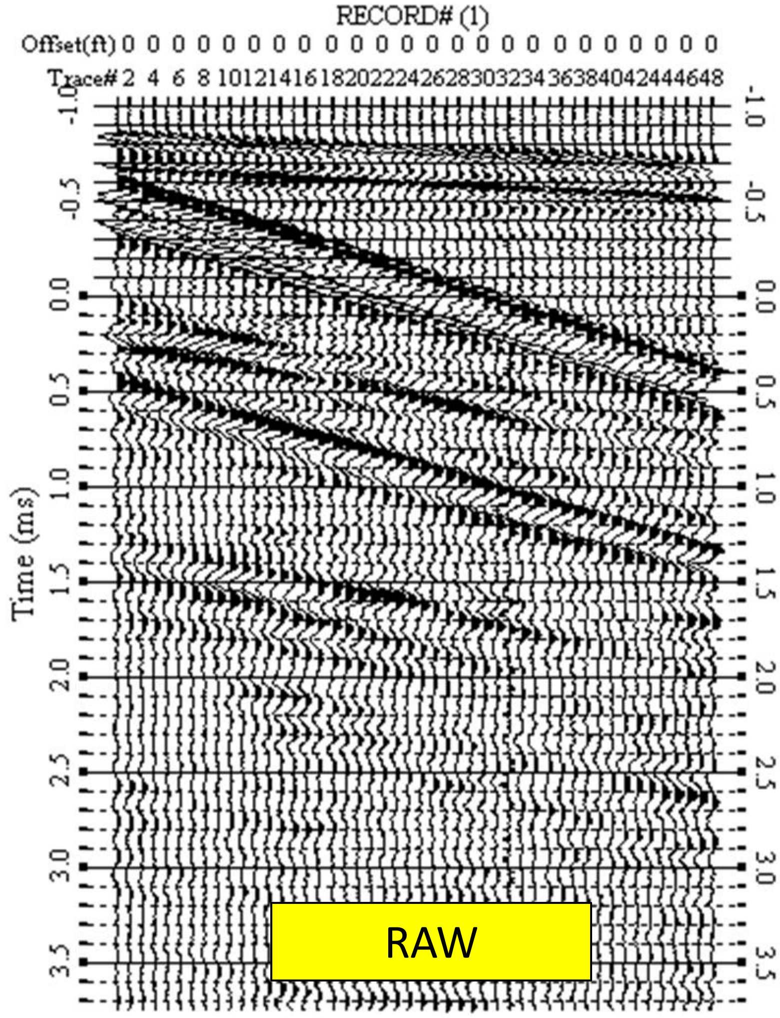
The LMO stack (its principle is graphically illustrated below) is commonly used to identify linear events on a multichannel seismic record. The stack can then be utilized for various purposes. For example, energy peaks in the stack can be used to identify occurrence time and phase velocity of both Lamb and air wave events. This information can be further used for many other purposes including QA/QC control of obtained record to evaluate the signal (Lamb)-to-noise (air) ratio to determine whether it is to be used for subsequent process or not.



LMO Stack of Field Record (48-Channel)

A 48-channel field (raw) record is used to construct an LMO stack, which shows many energy peaks, indicating there are many linear events identified in the field record.





LMO Stack of Field Record (48-Channel)

Display of LMO stack has now muted all energy levels lower than 50% of the maximum to emphasize only those peaks of significant (e.g., > 50%) energy. Each peak in the LMO stack is associated with the corresponding linear event in the field record by a red arrow.