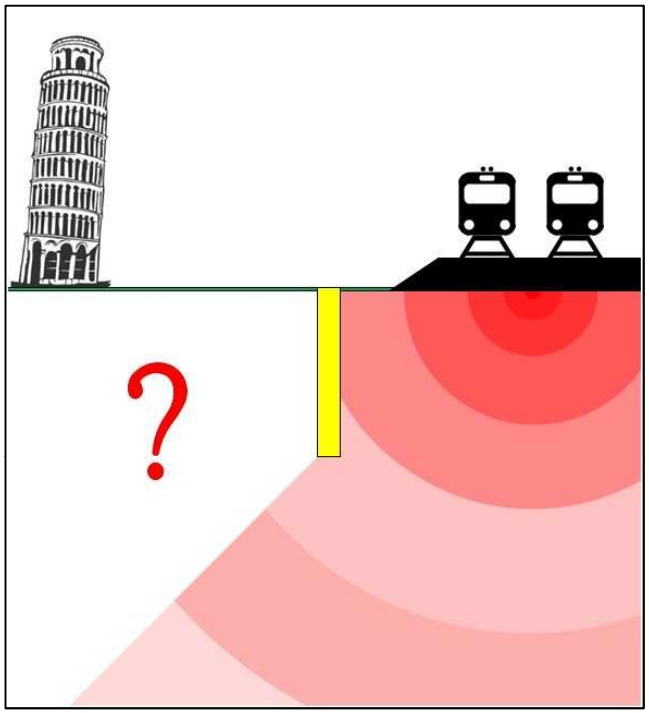
Soft wave barriers for railway induced ground vibration

David Thompson, ISVR

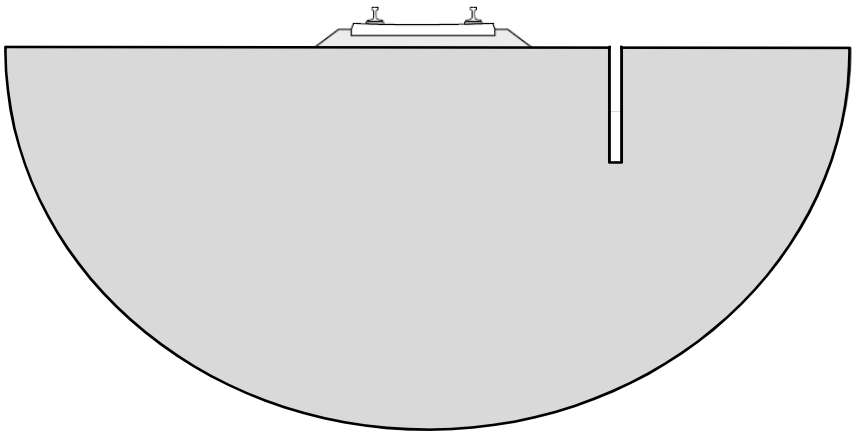
Open trench

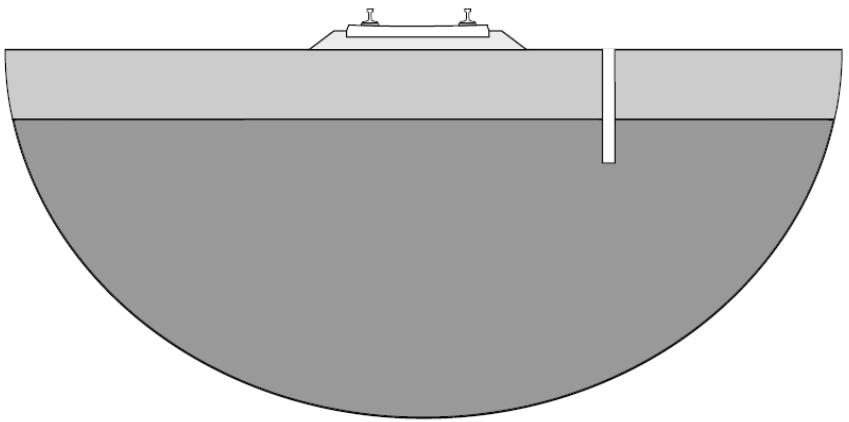
- First consider an open trench
- A trench should work like a noise barrier…



Open trench

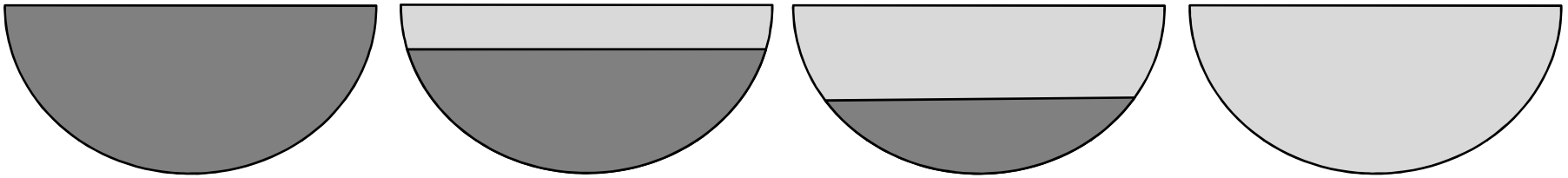
- For a trench in a half-space empirical results suggest 75% reduction achieved if depth is greater than $0.6\lambda_R$
- Typical wavelengths are 5-10 m, trench should be 3-6 m deep
- In a layered soil potential benefit expected if the trench penetrates through soft upper layer



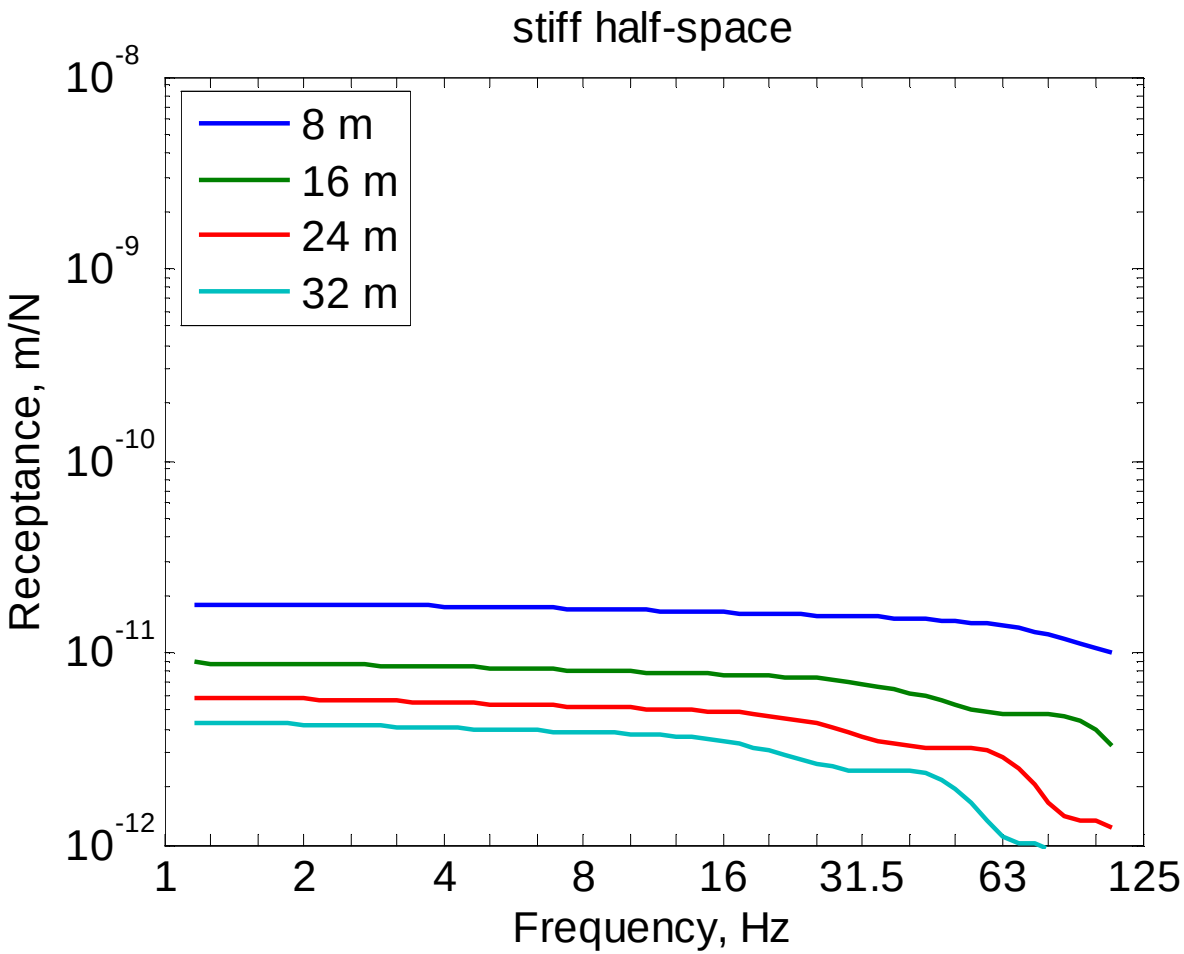


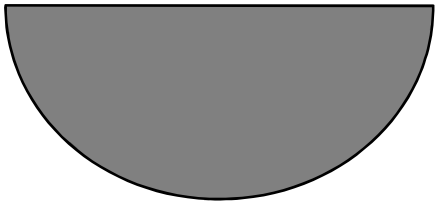
Initial design calculations

- Soft upper layer c_s = 150 m/s
- Stiffer half-space c_s = 600 m/s
- Layer depth: 0, 3, 6 m and infinite are considered
- Used 2D FE/BE model

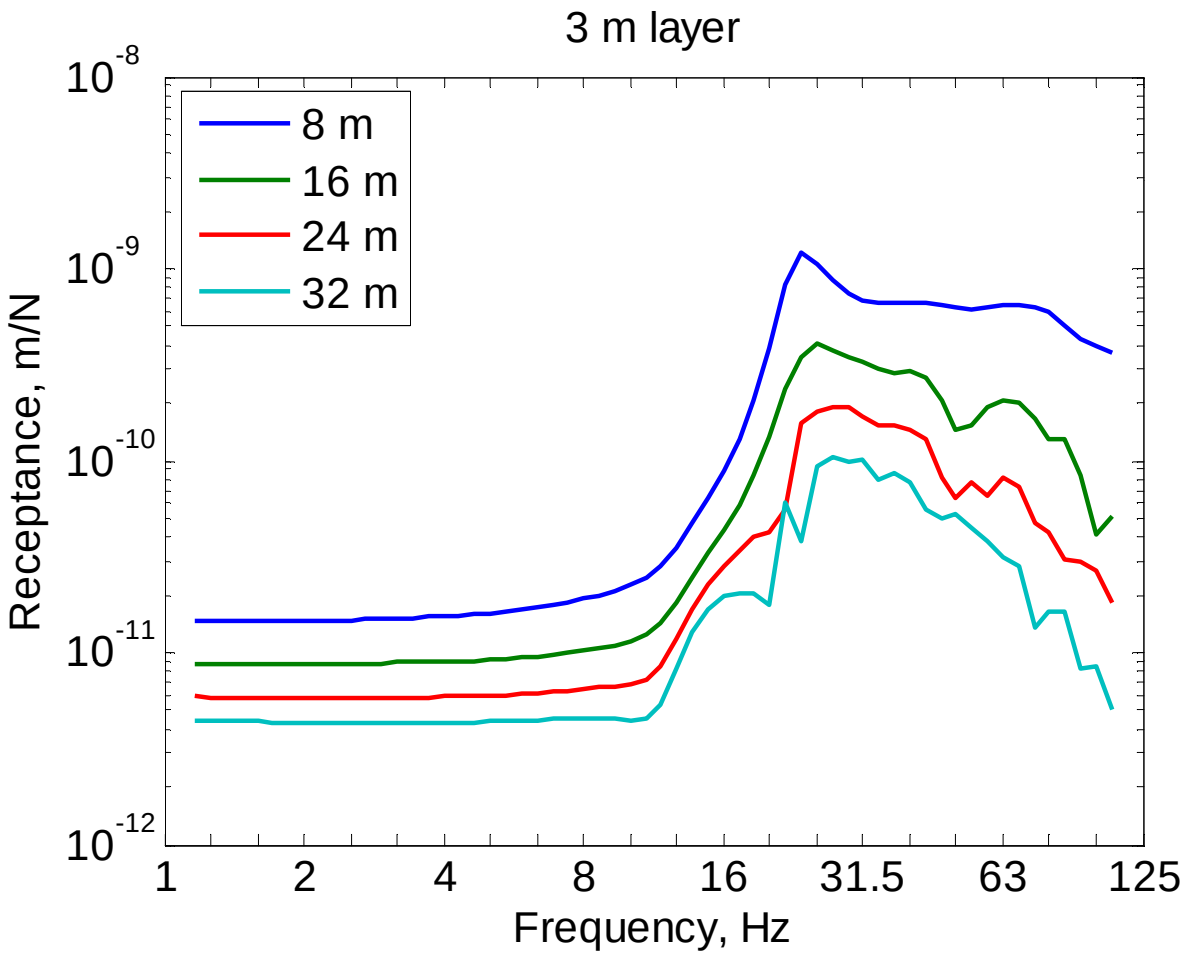


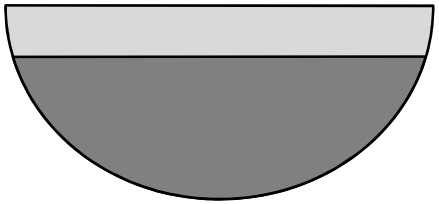
Transfer functions 0 m layer



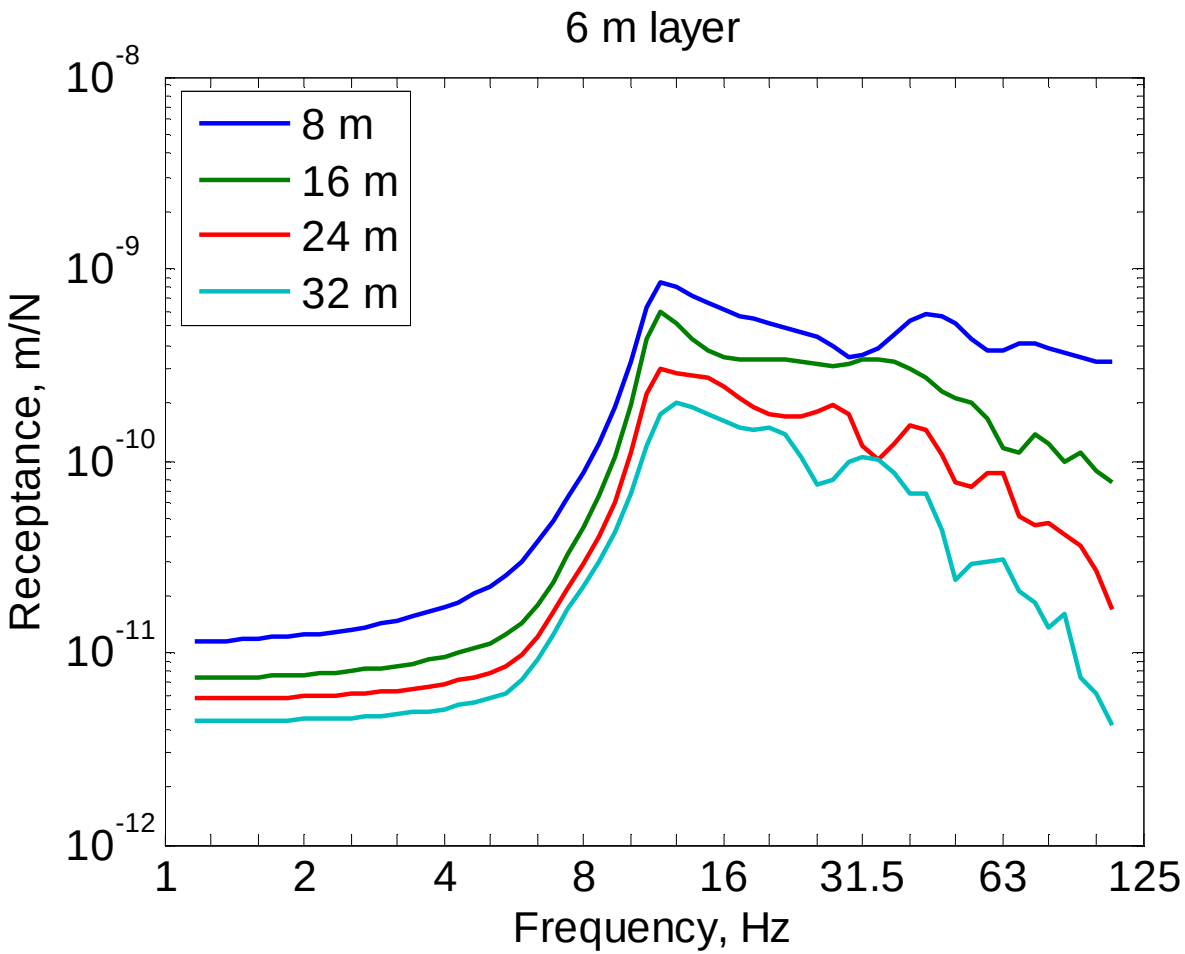


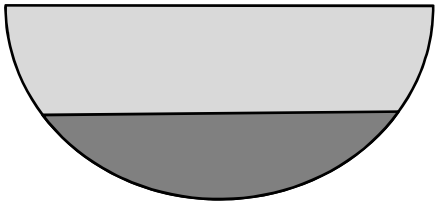
Transfer functions 3 m layer



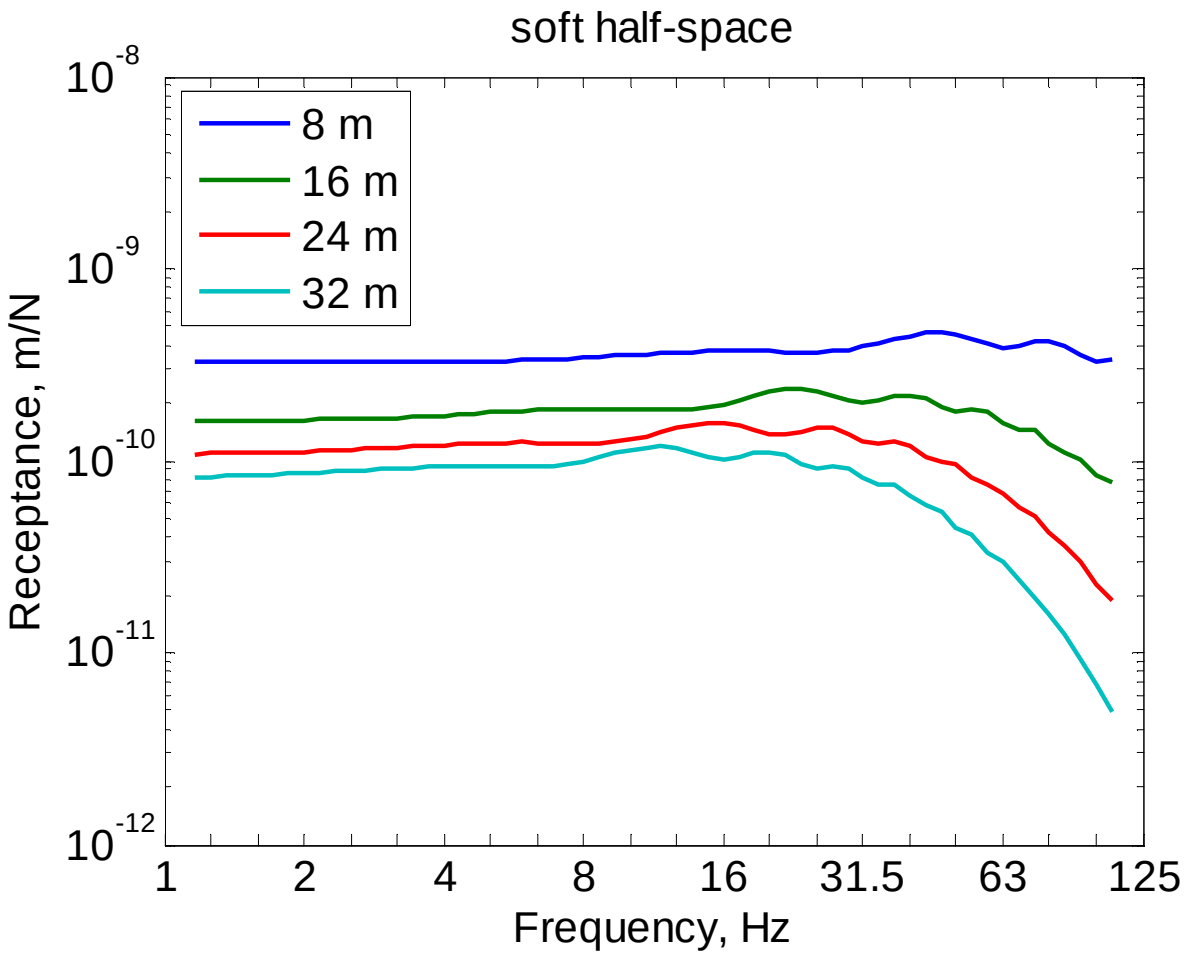


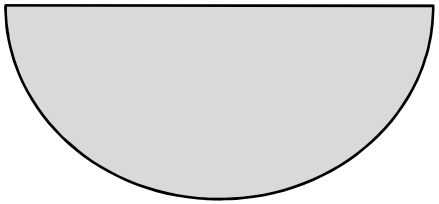
Transfer functions 6 m layer



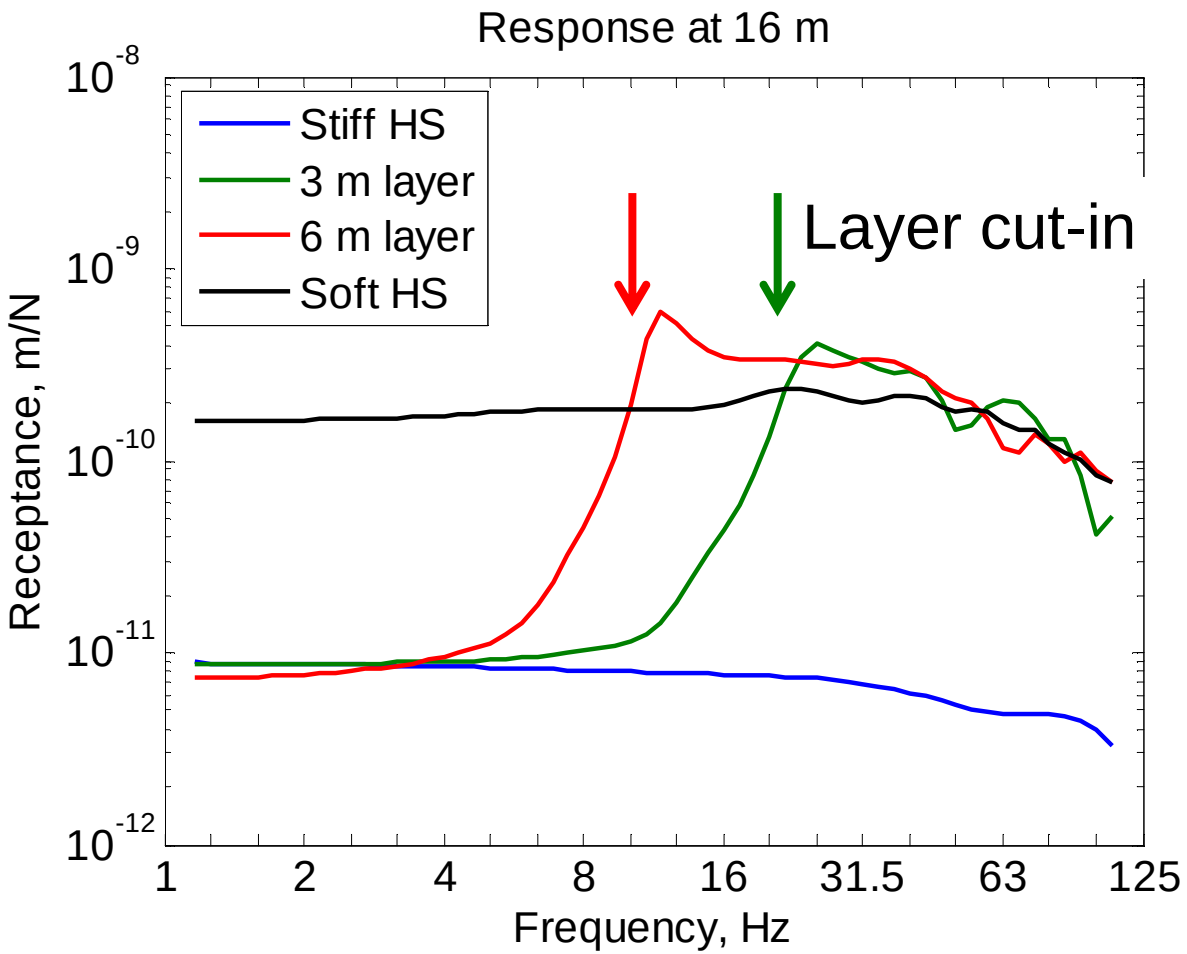


Transfer functions ∞ layer

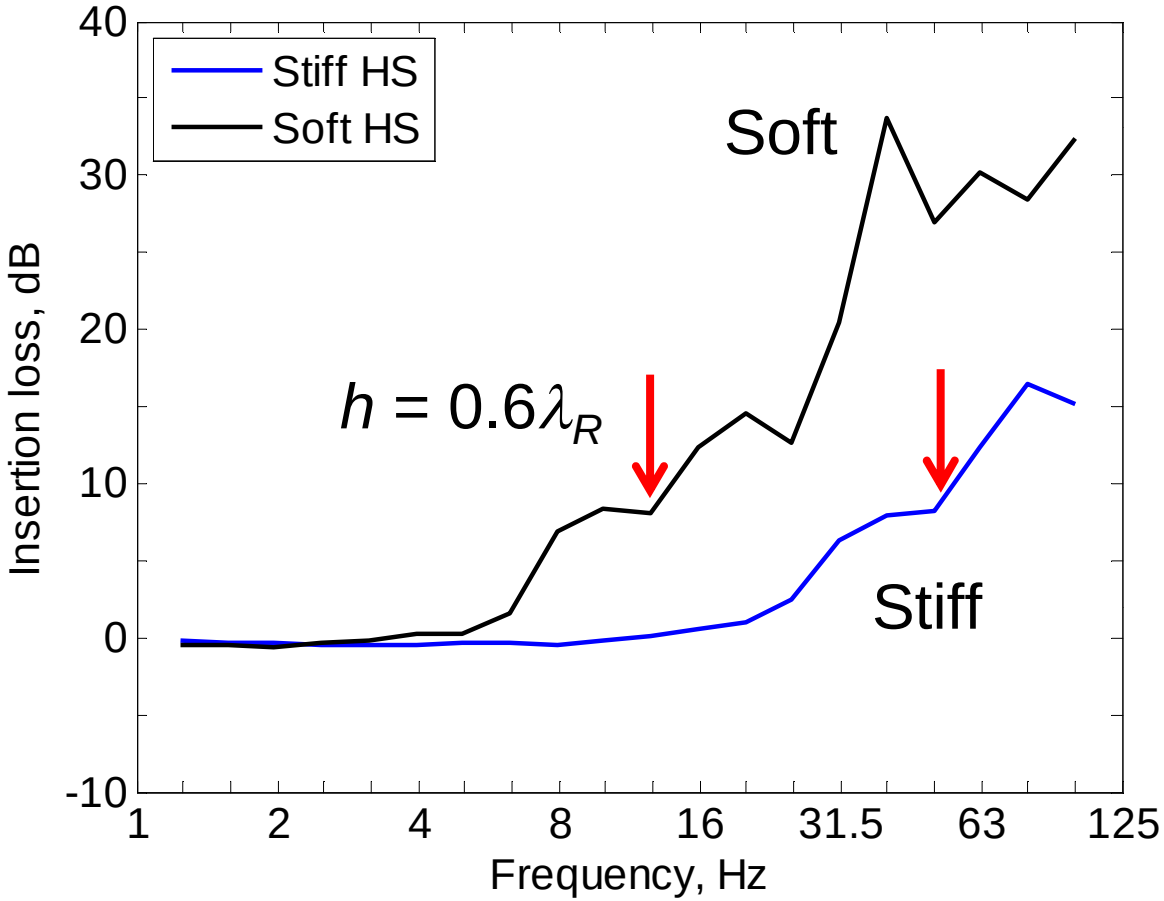


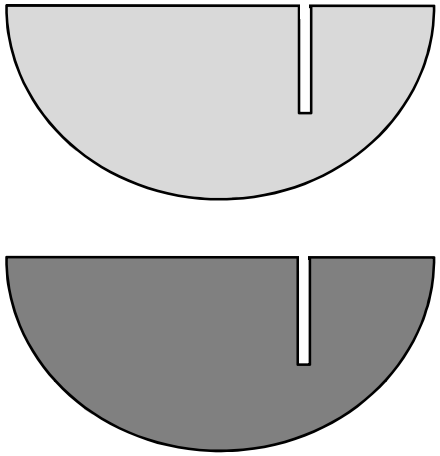


Transfer functions

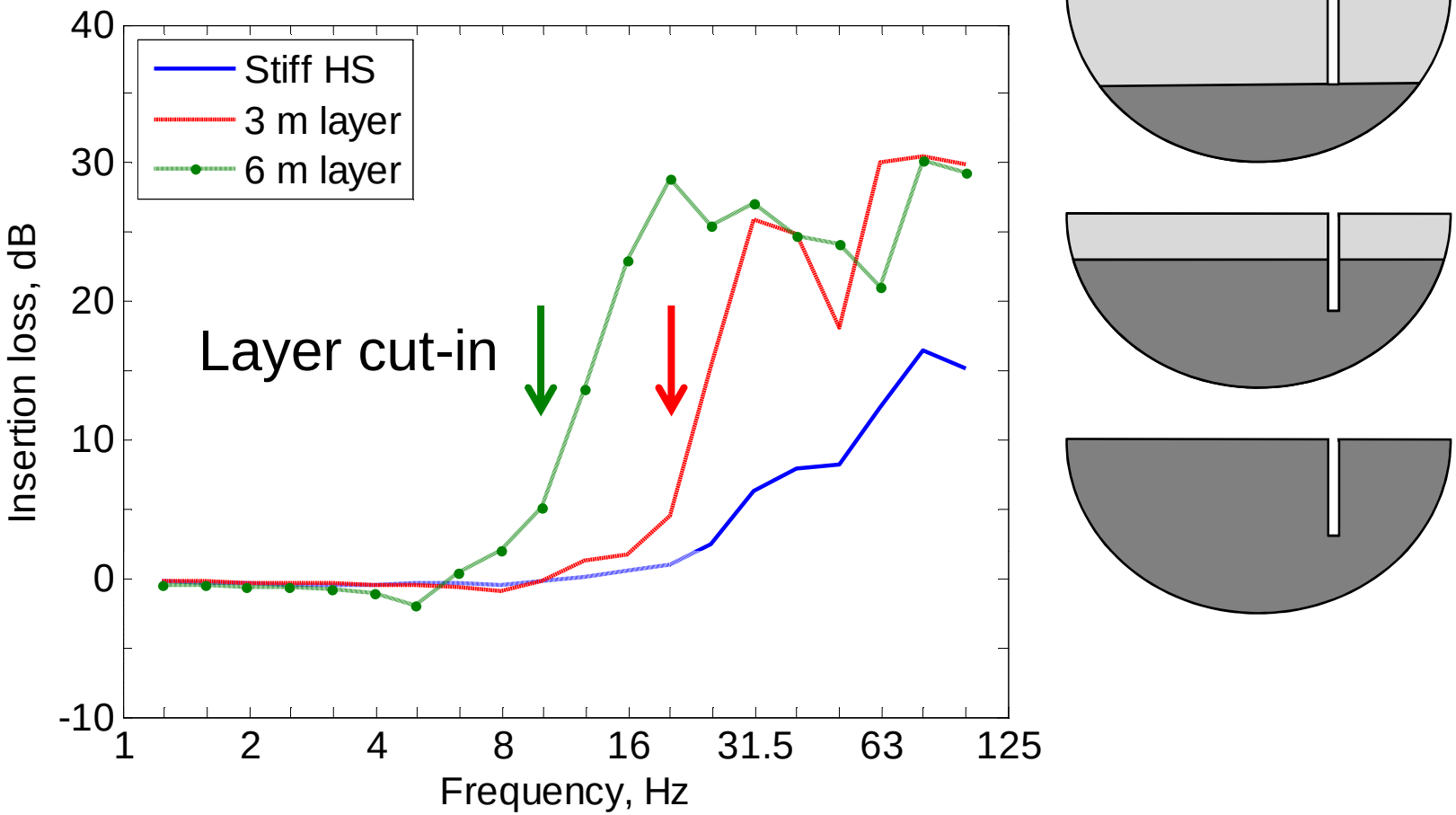


6 m trench (half-space)

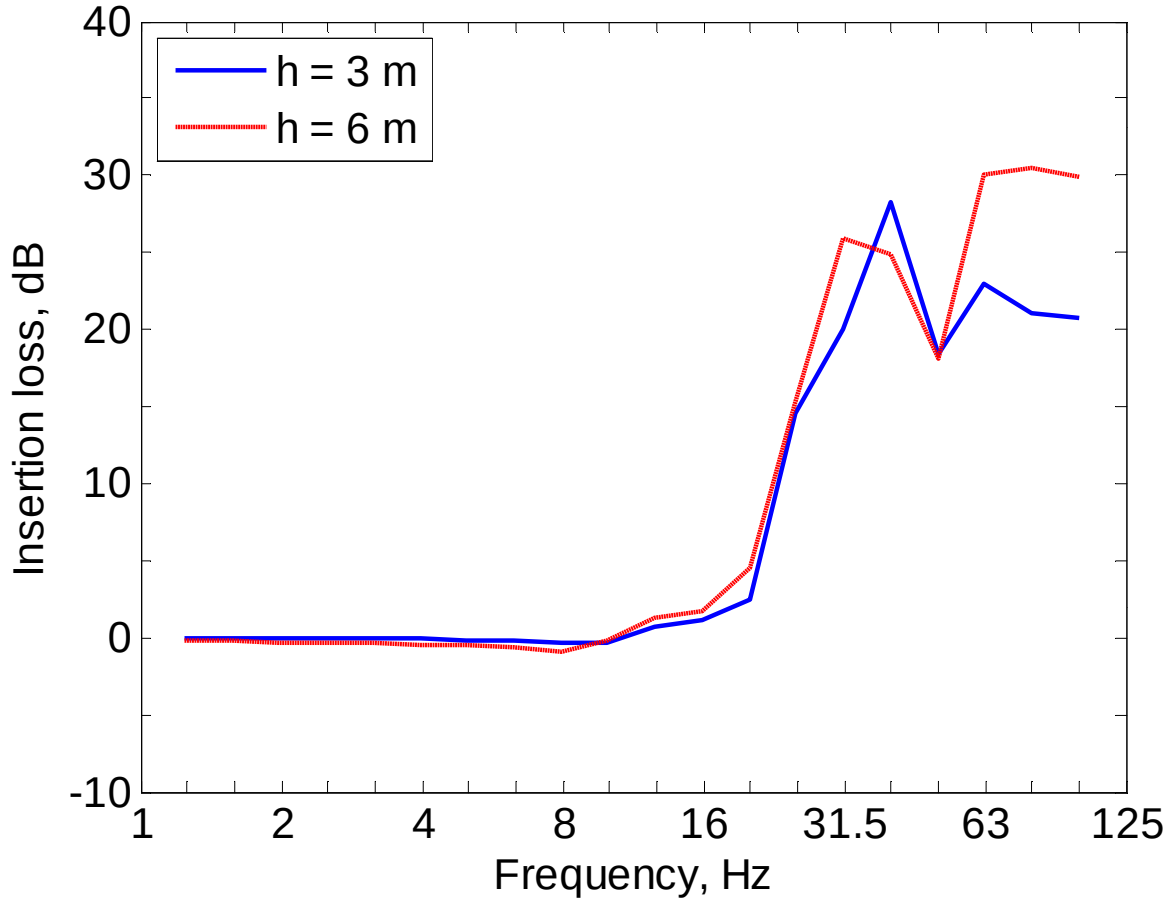


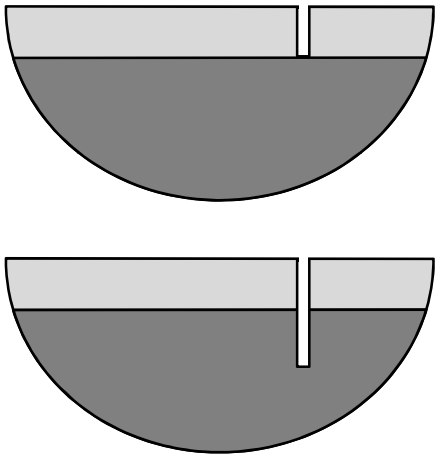


Effect of layer depth (6 m trench)



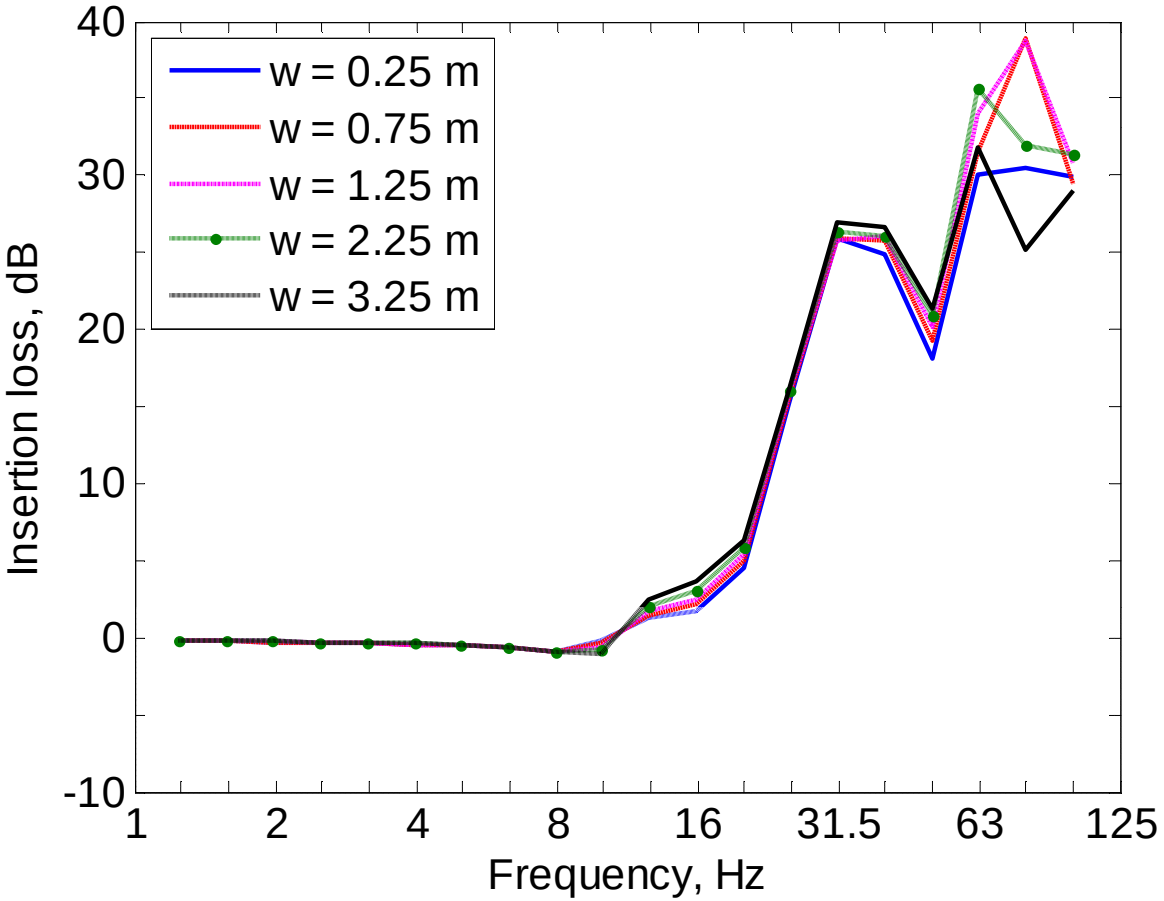
3m layer: 3 or 6m trench

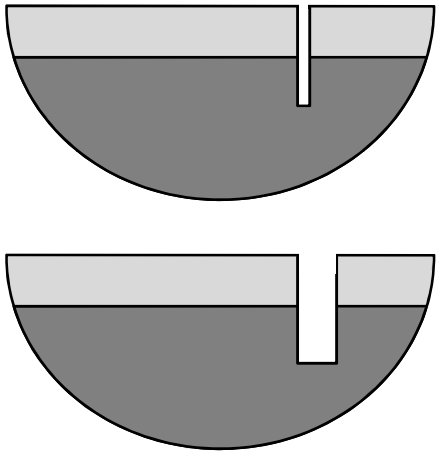




It is sufficient to penetrate the soft layer

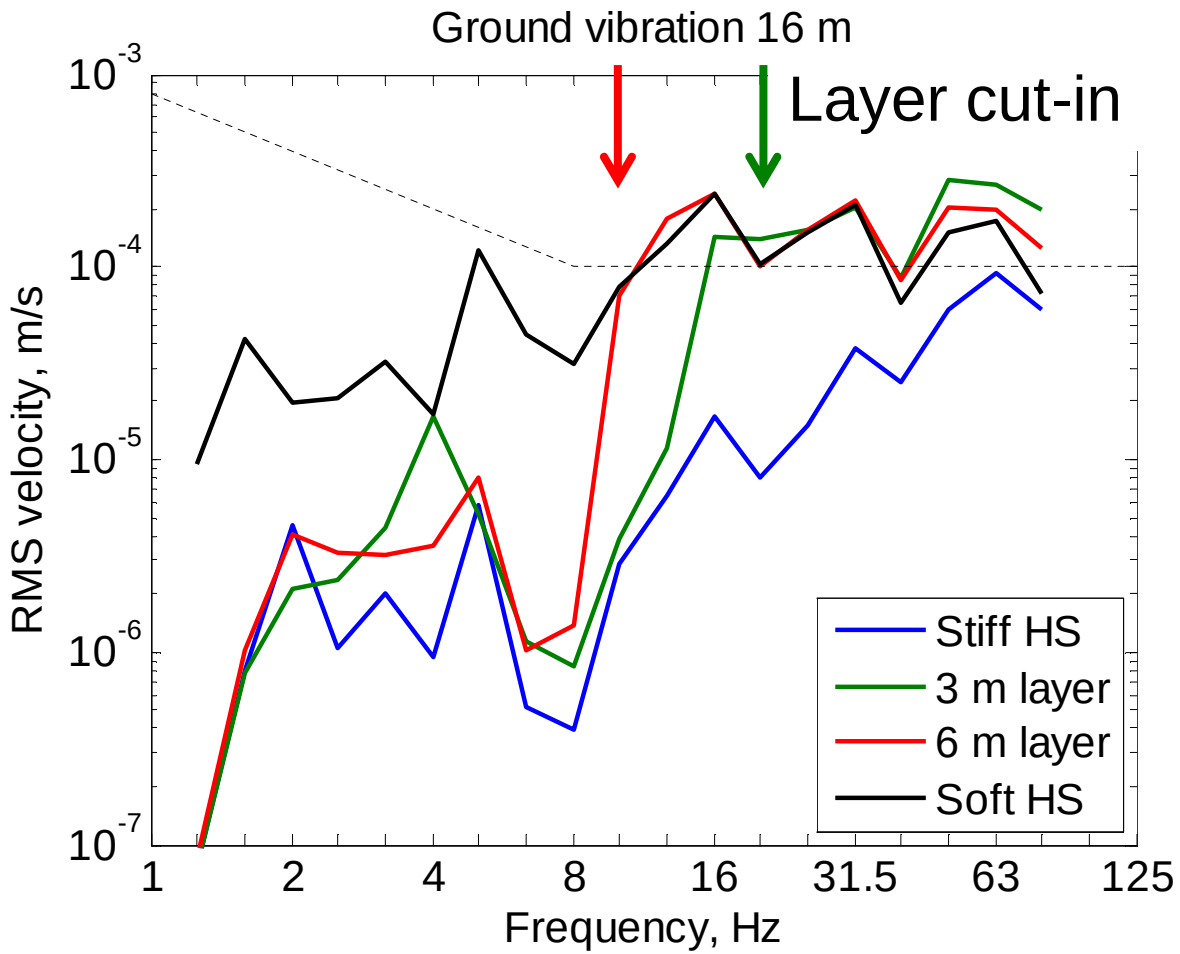
Effect of trench width



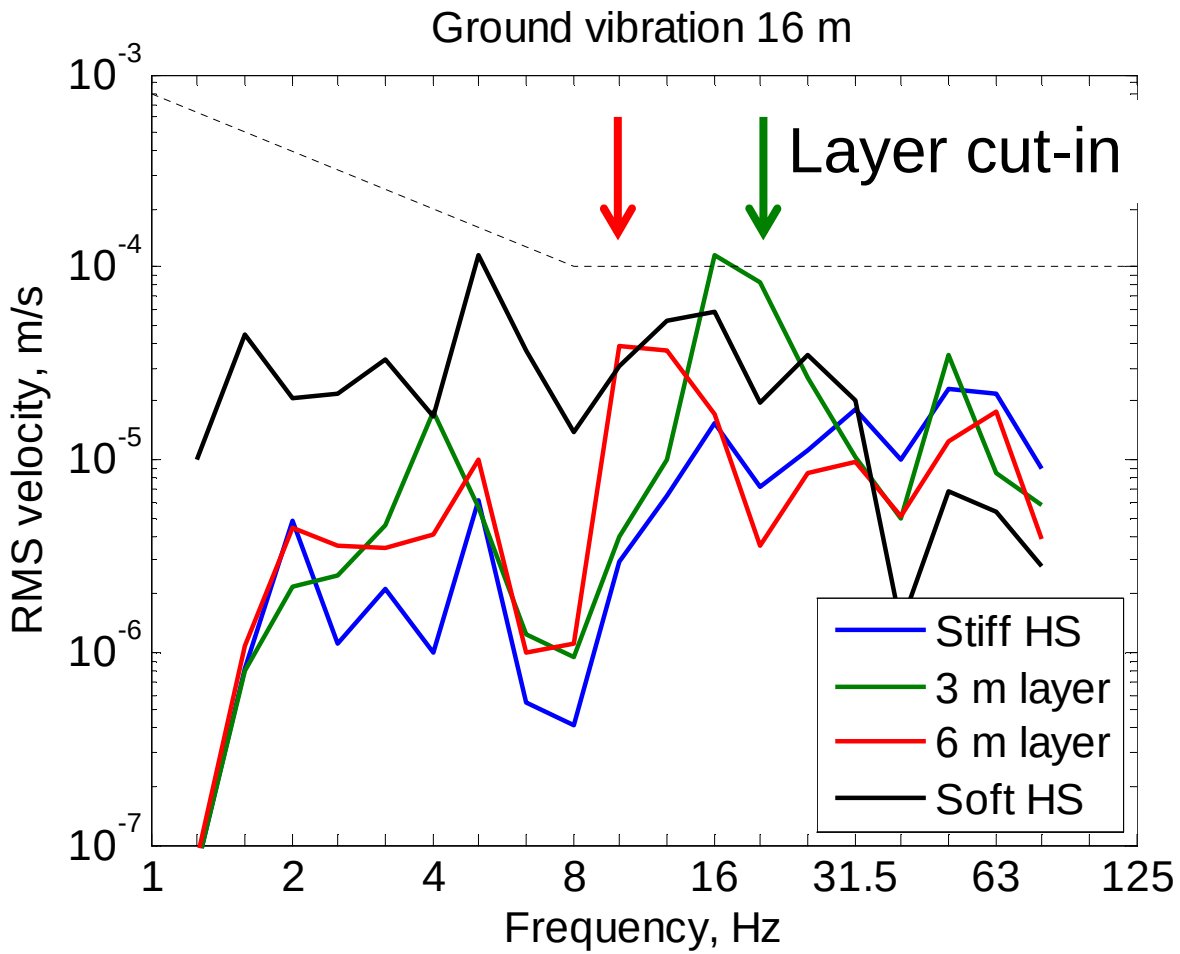


Width is less important than depth

Ground vibration from trains



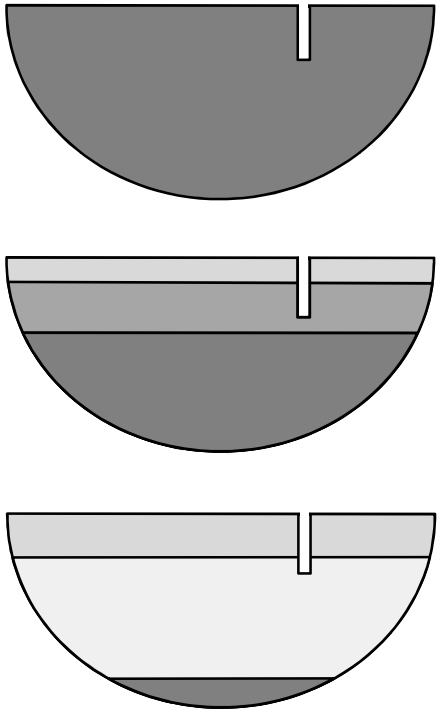
Ground vibration with 6 m trench



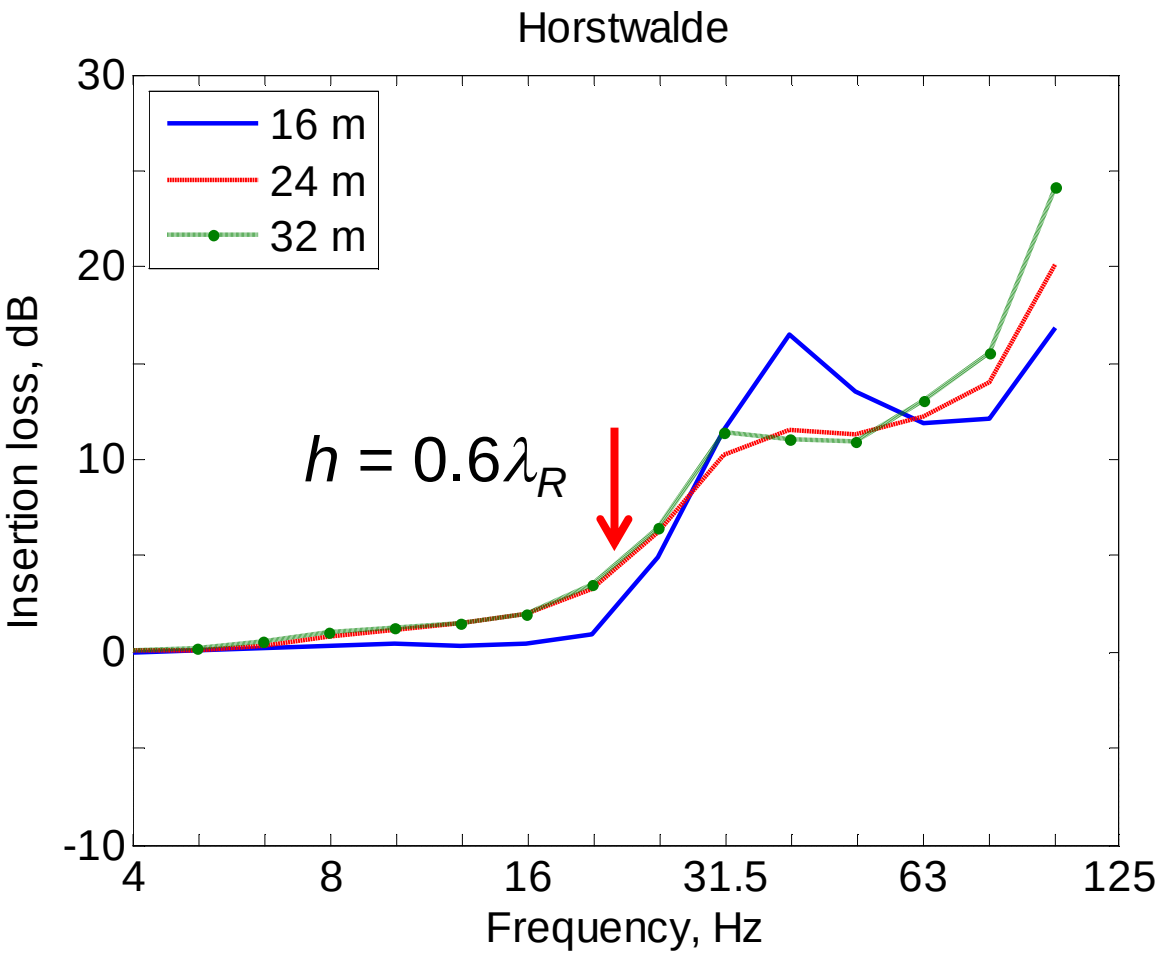
Calculations for reference sites

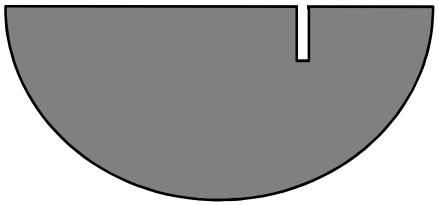
- Horstwalde: homogeneous 250 m/s
- Lincent: soft layers 1.4 + 2.7 m deep
- Furet: soft layers 2 + 10 m deep

- Used 2.5D FE/BE model

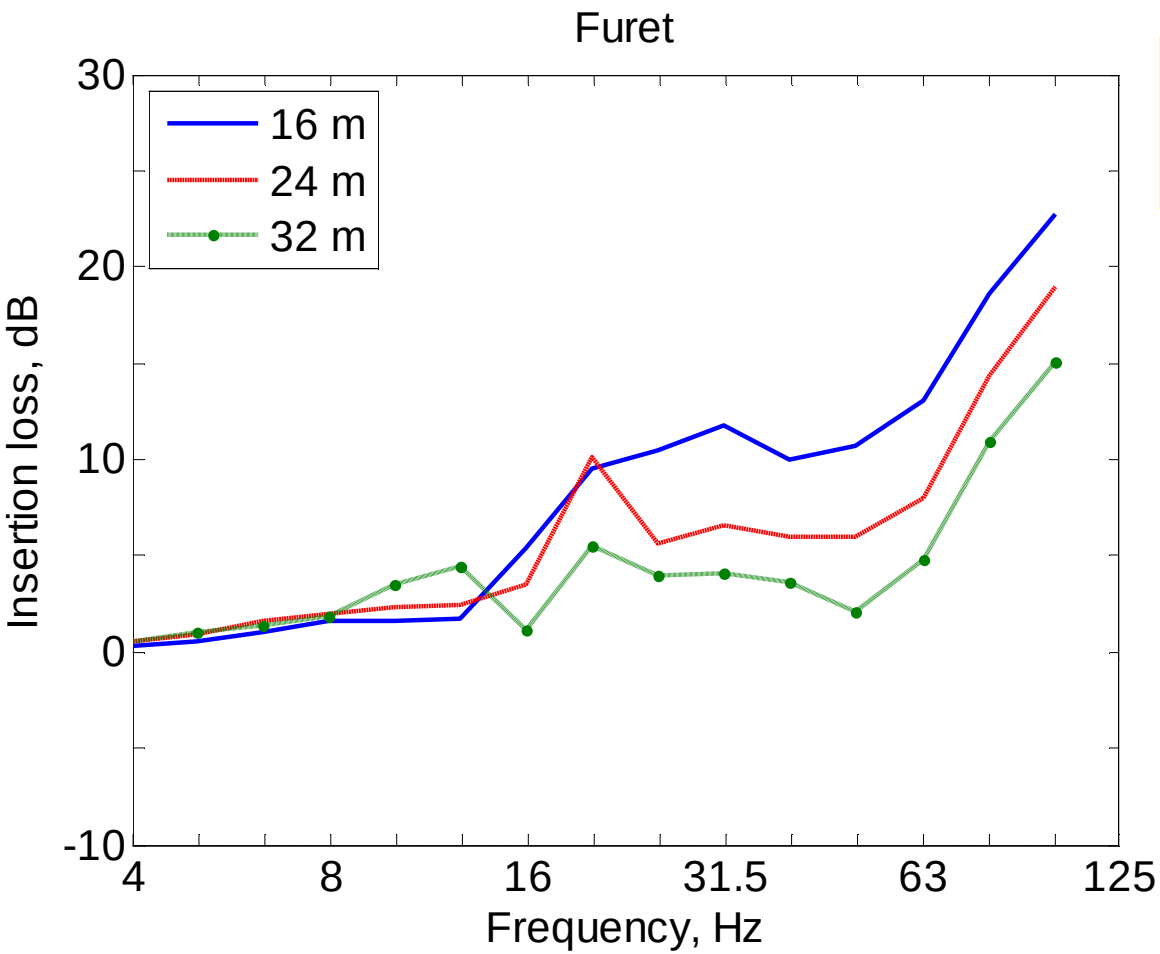


Horstwalde: 3 m deep trench

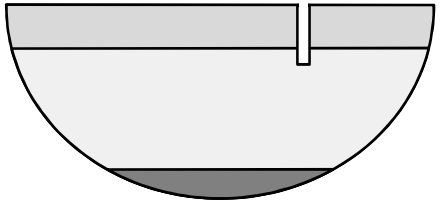




Furet: 3 m deep trench

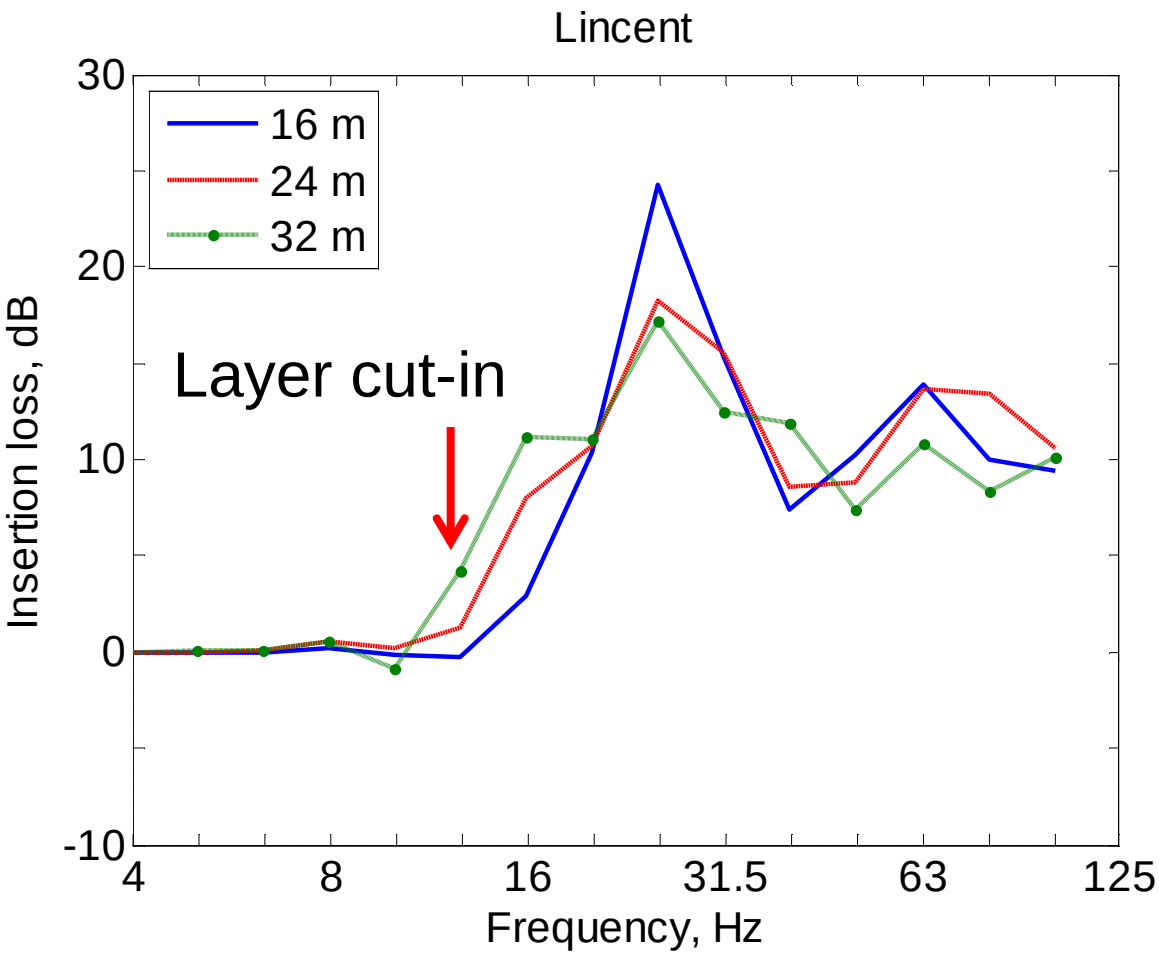


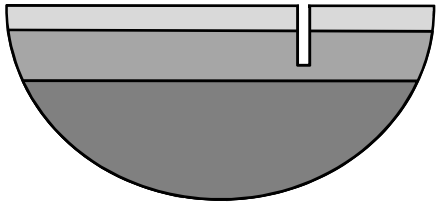
Effect reduces with distance



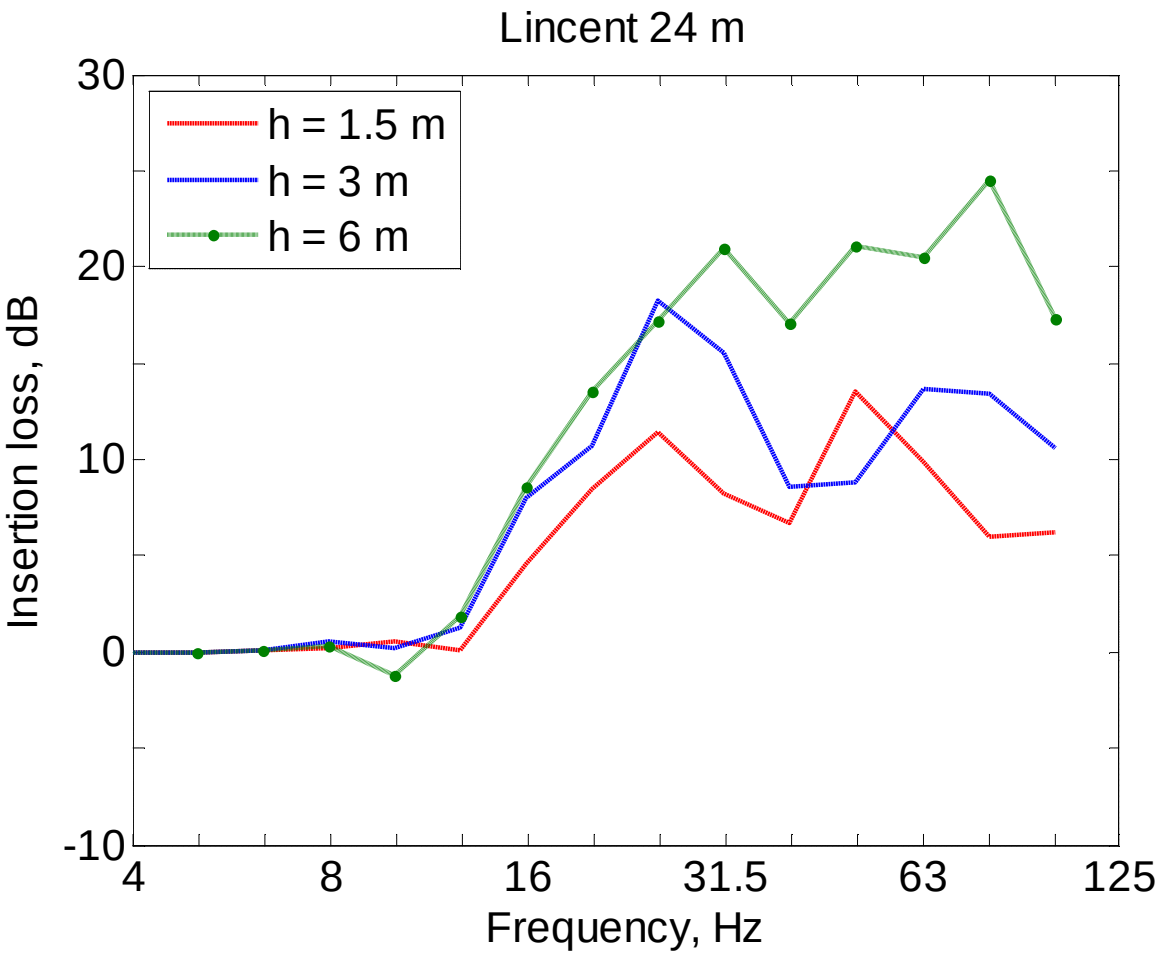
Trench does not penetrate the soft upper layer

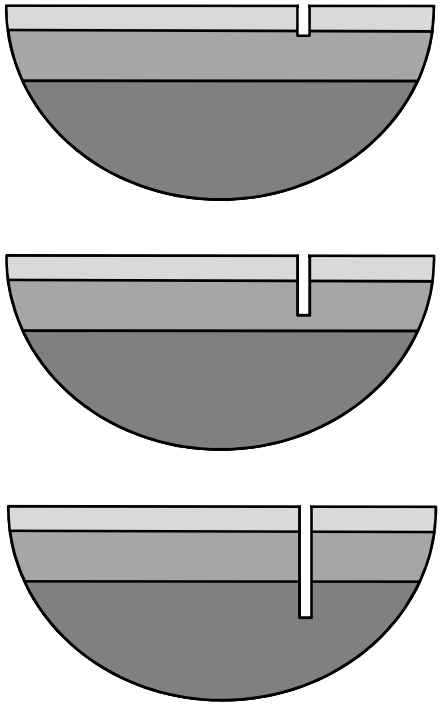
Lincent: 3 m deep trench





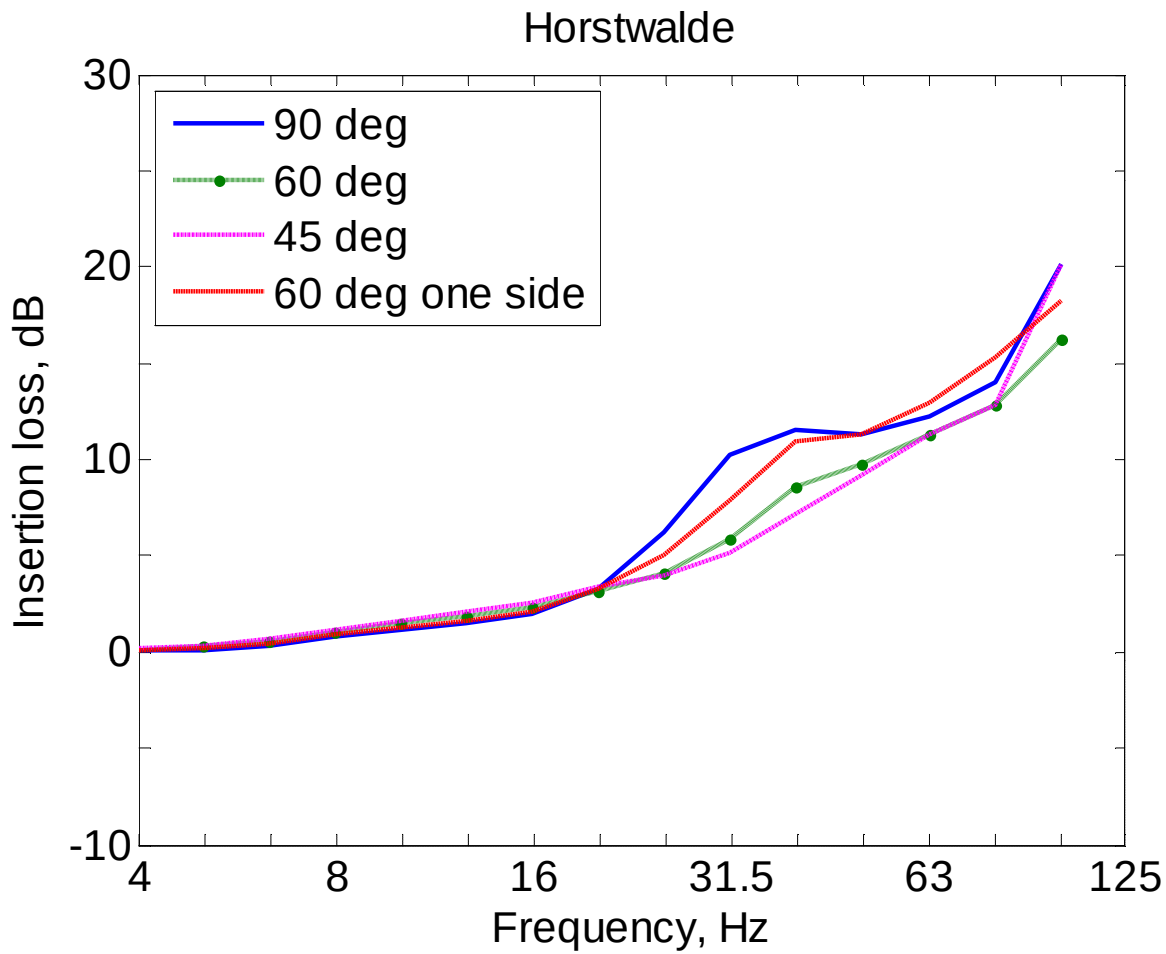
Lincent: trench depth

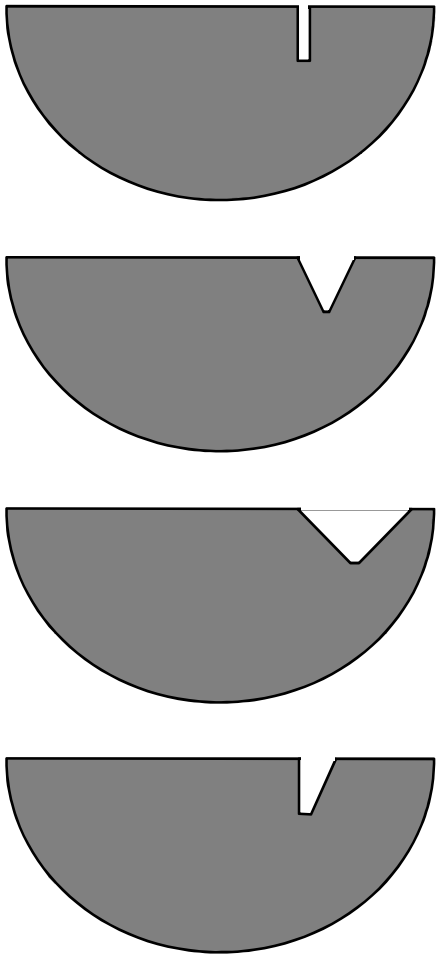




Better if penetrates both layers

Sloping sides





Open trench – summary

- In a layered soil, a trench is beneficial when it cuts through the soft upper layer
- Benefit is only found above ‘cut in’ frequency of the upper layer
- …but this is frequency region where highest vibration levels are expected
- Benefits of 20+ dB predicted
- But a 6 m deep open trench is not practical…
- …fill with a soft barrier material.

Soft barrier

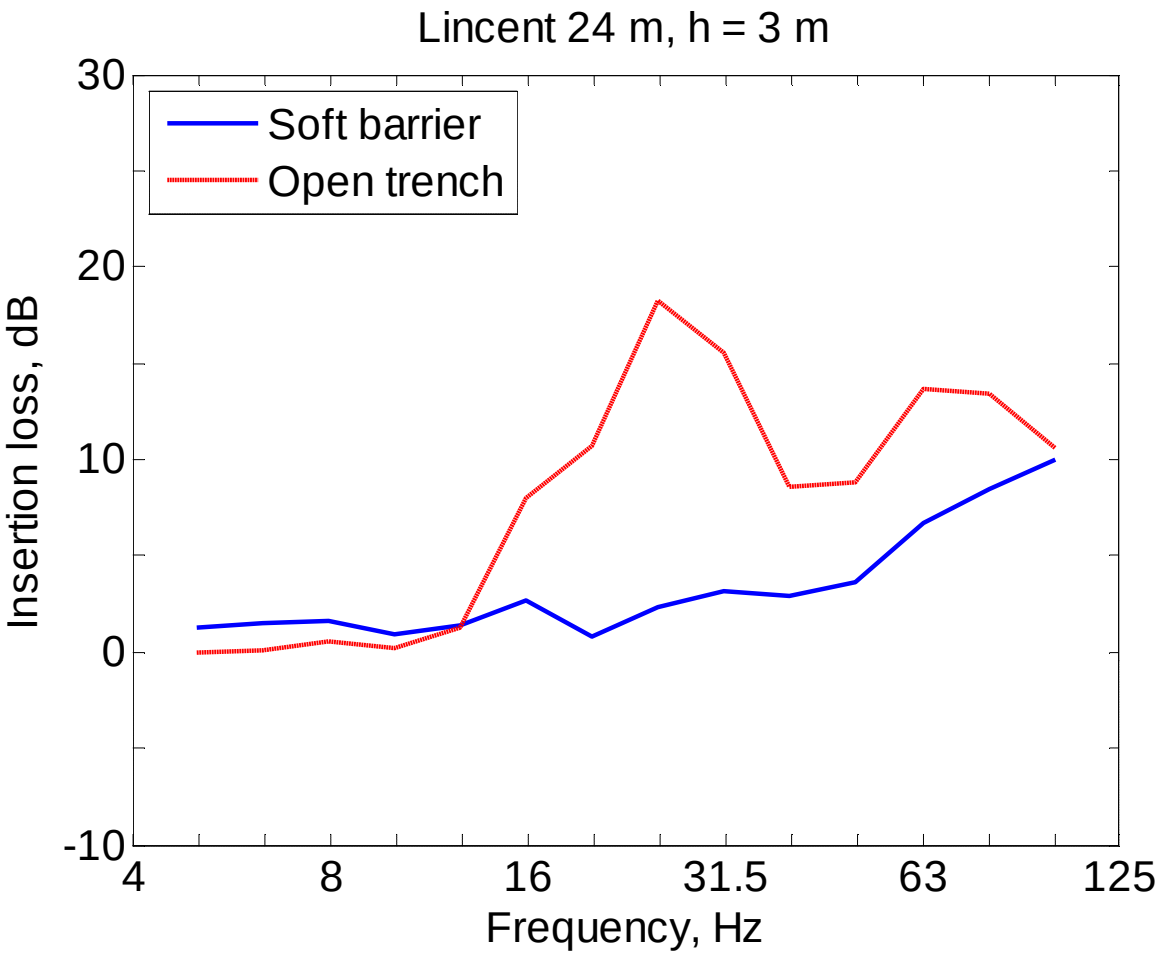
- 5 cm wide
- Typical isolation mat material
- Young's modulus ~100 times softer than soil at Lincent
- 3 m or 6 m deep

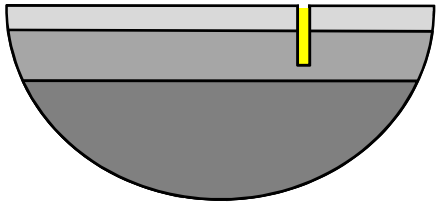
Results for three reference sites:

- Horstwalde: homogeneous 250 m/s
- Lincent: soft layers 1.4 + 2.7 m deep
- Furet: soft layers 2 + 10 m deep

- Used 2.5D FE/BE model

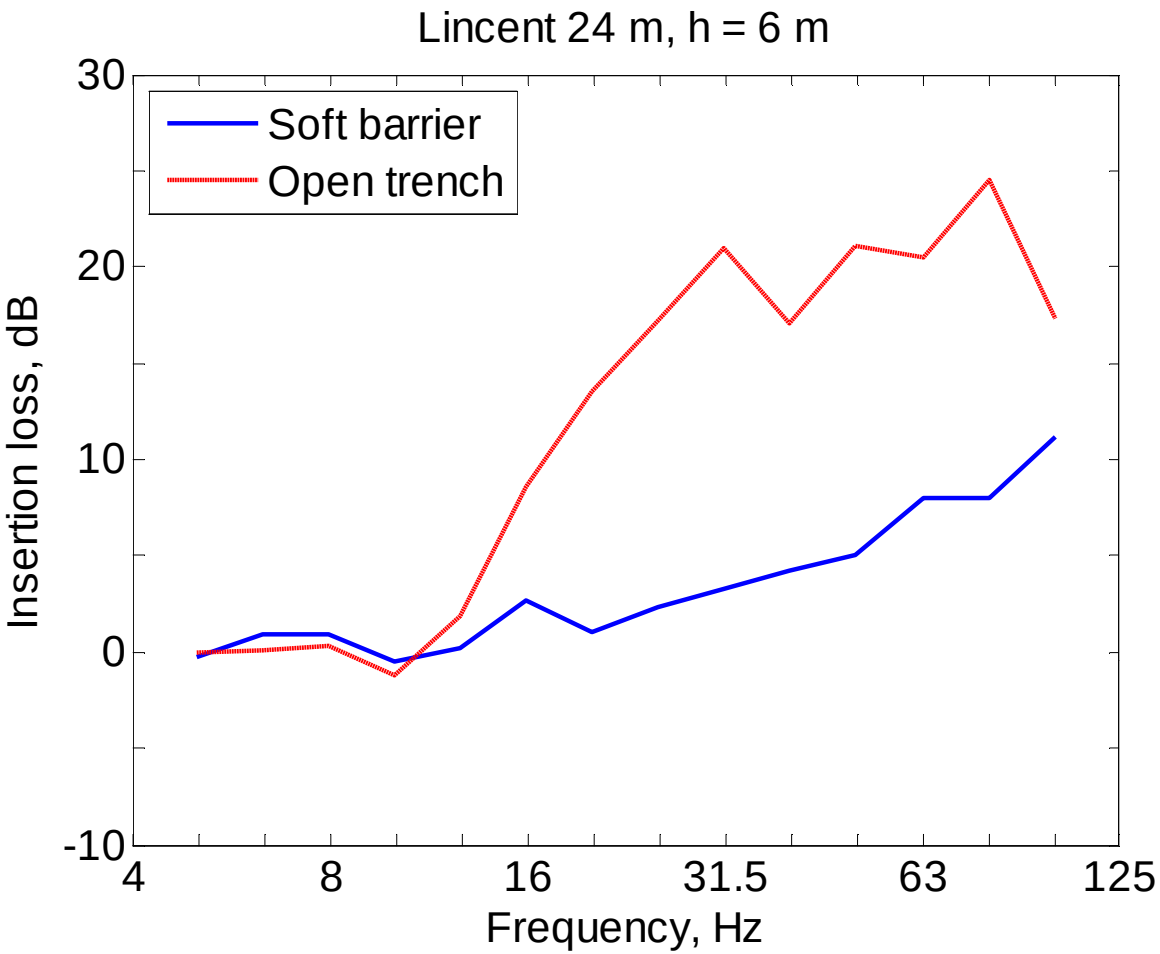
Lincent: soft barrier 3 m depth

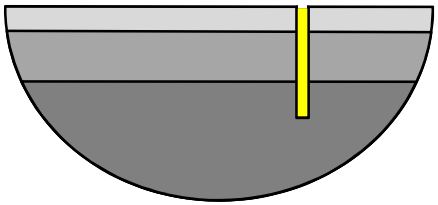




Much less effect than open trench

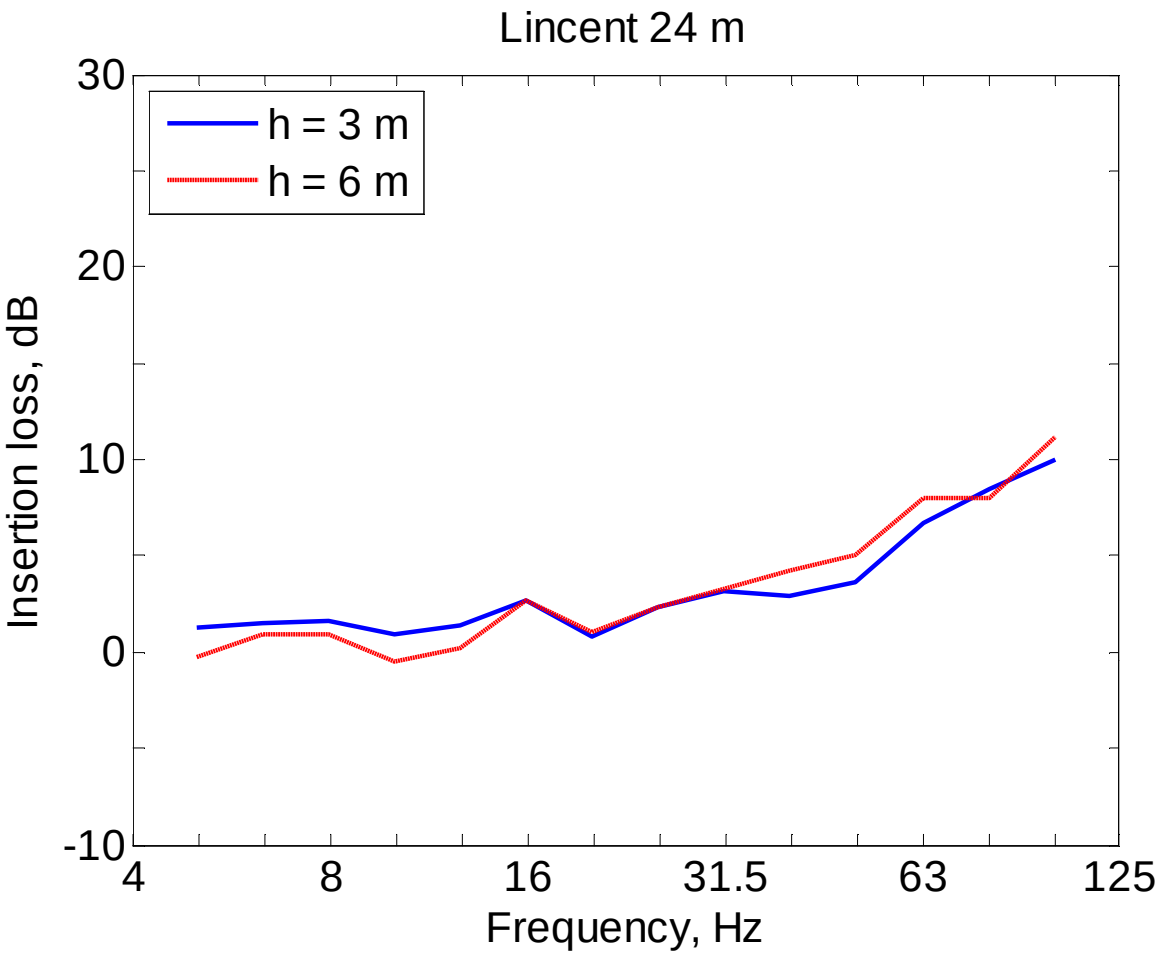
Lincent: soft barrier 6 m depth

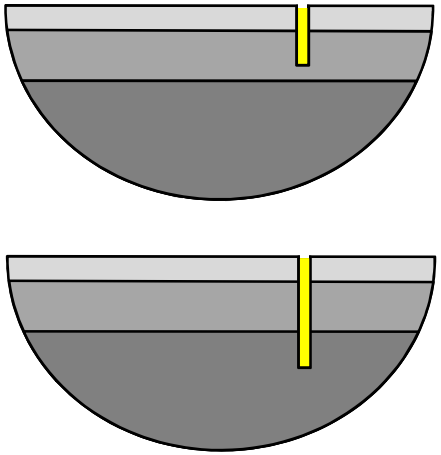




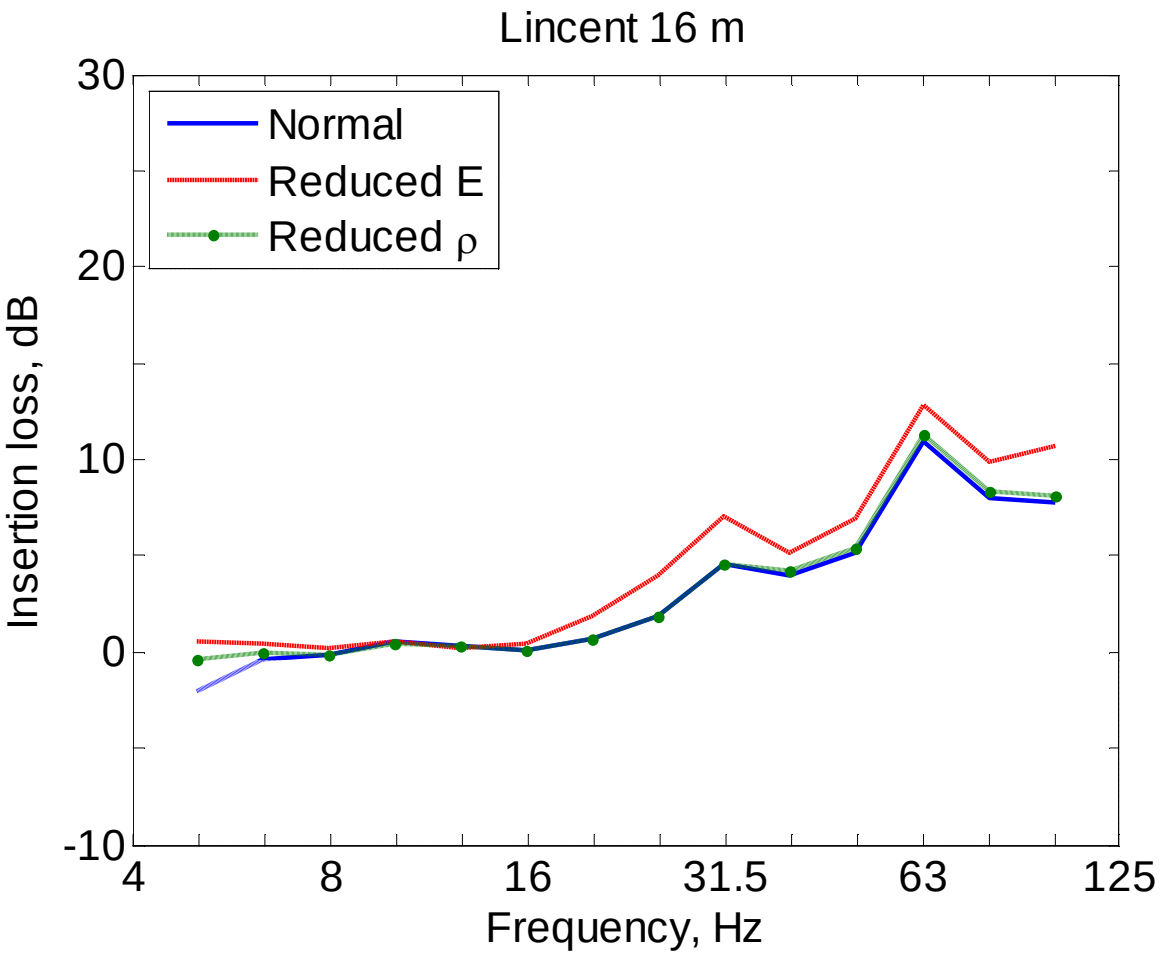
Much less effect than open trench

Lincent: soft barrier depth

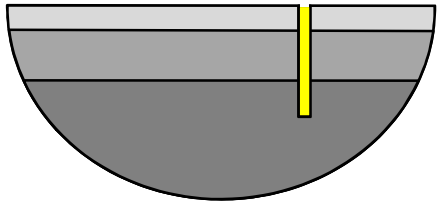




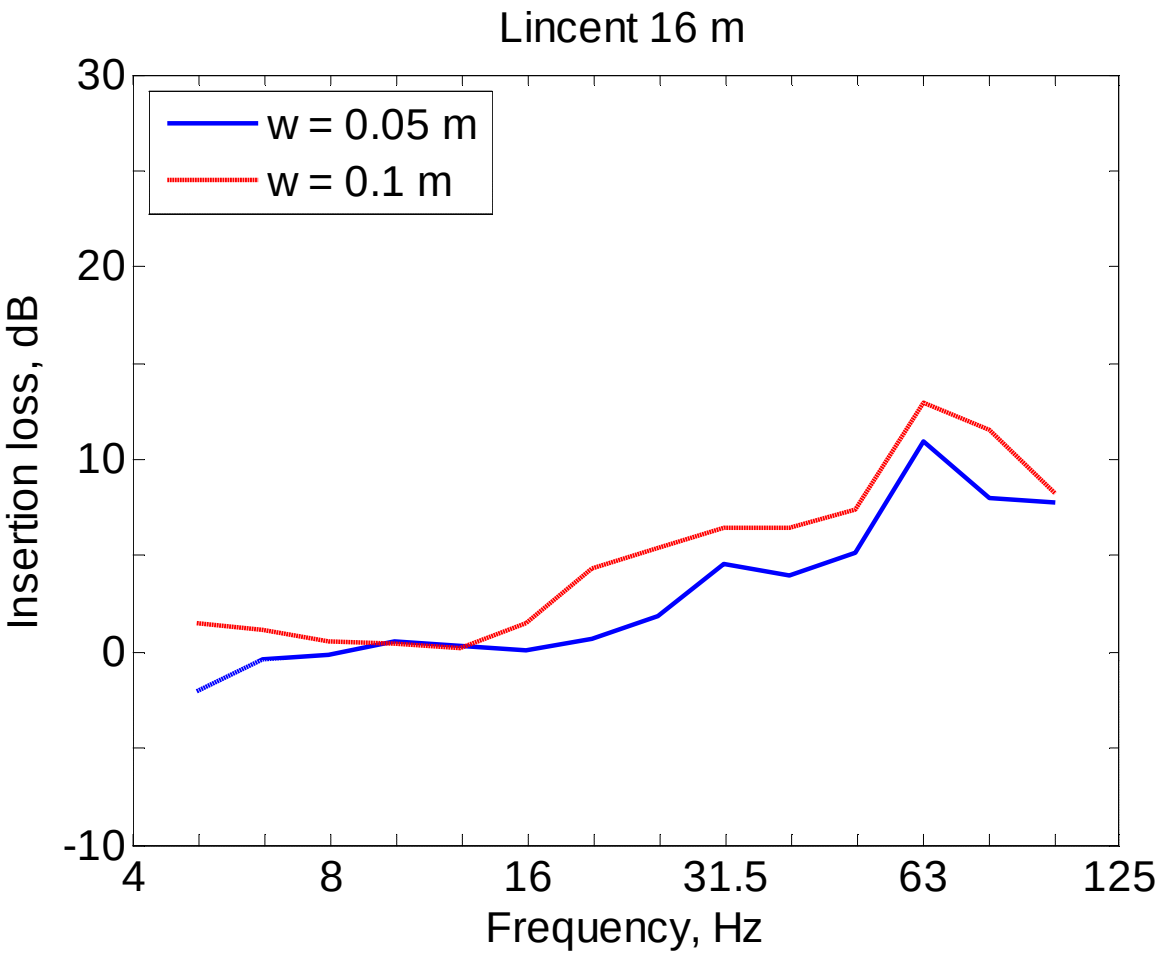
Lincent: soft barrier material (6 m)



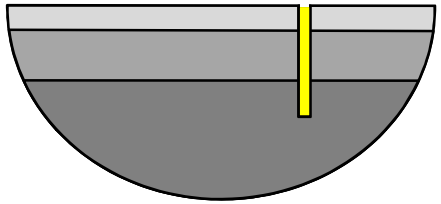
Stiffness of fill material is important, not impedance or wave speed



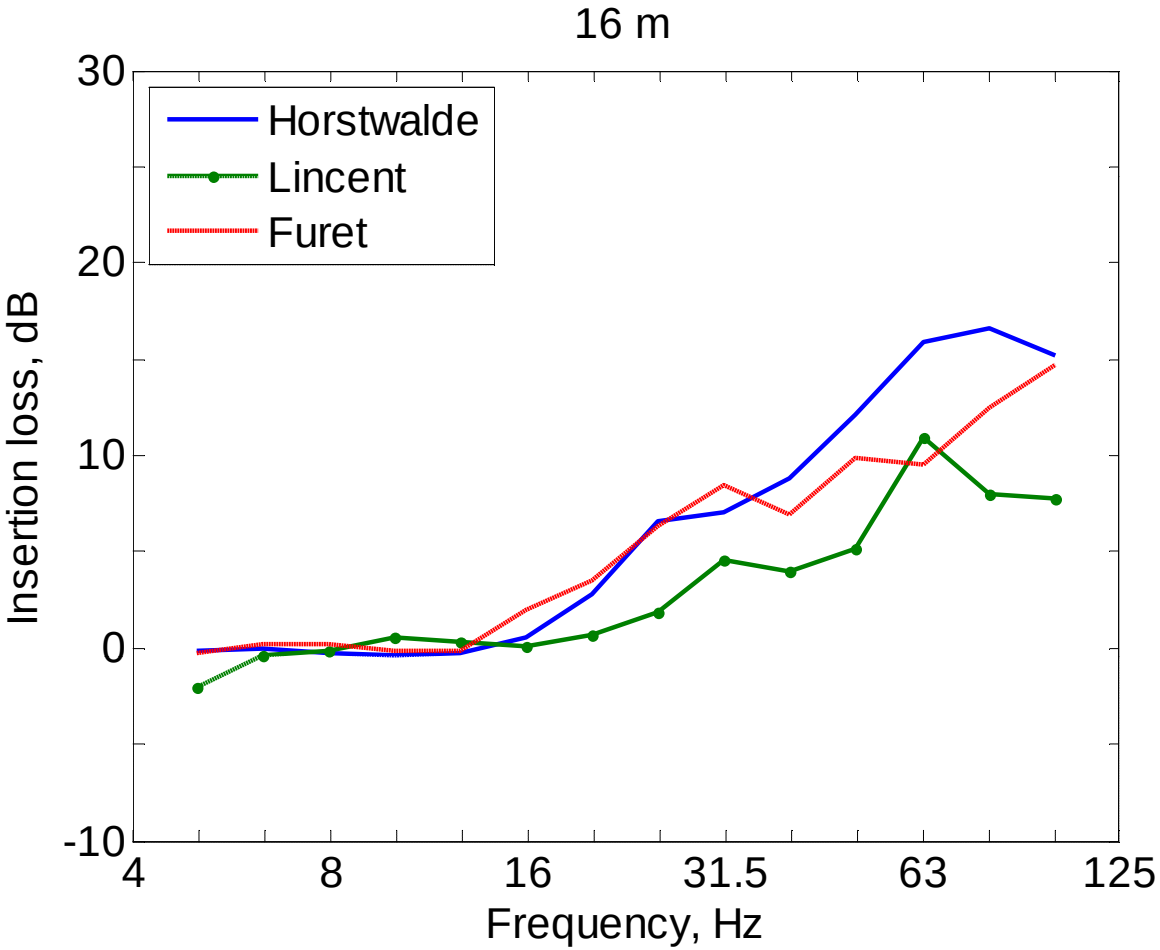
Lincent: soft barrier width (6 m)



Increased width means lower stiffness

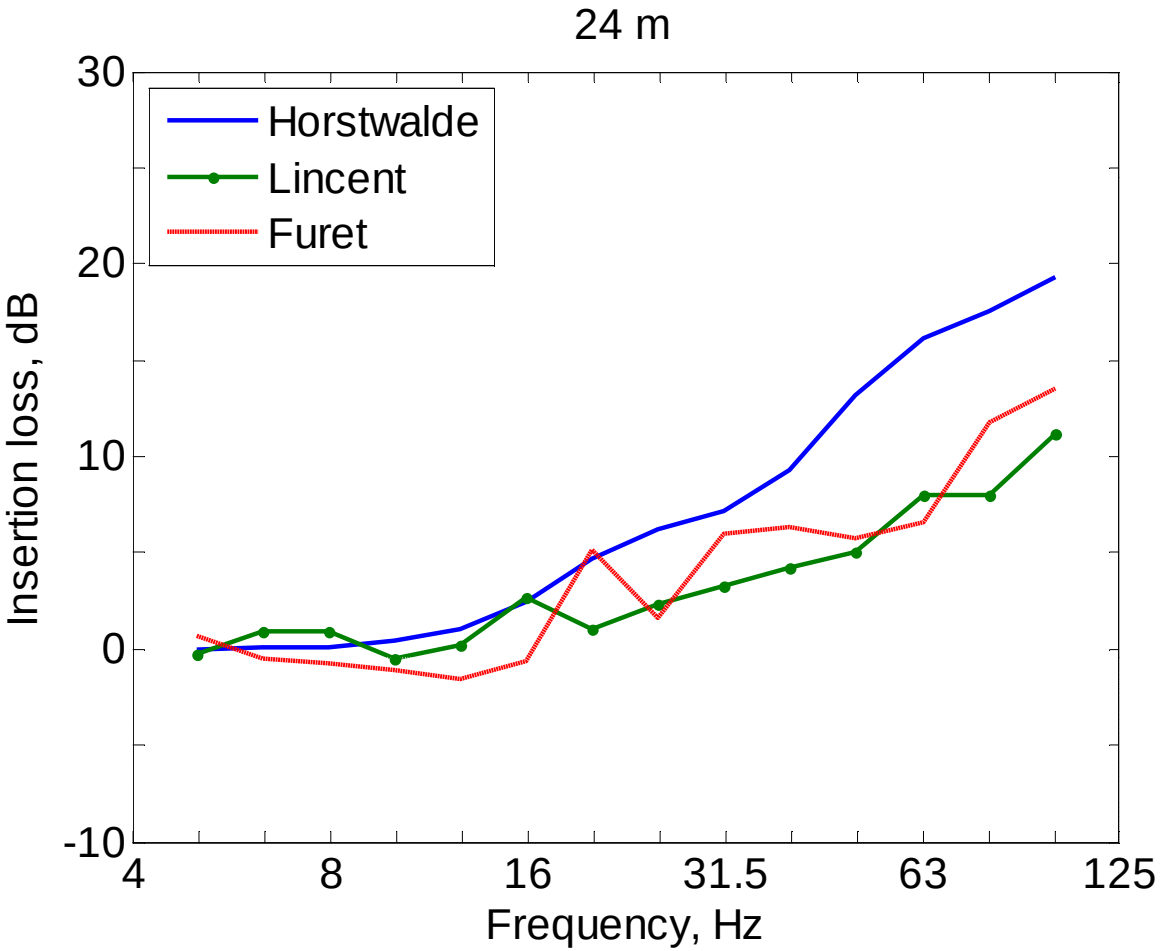


6 m soft barrier, different soil conditions



Works better at Horstwalde (stiffer soil) than Lincent

6 m soft barrier, different soil conditions



Result for Furet reduces with distance

Field tests

- It was intended to install a soft barrier in Switzerland and test its performance.
- Various test sites were investigated but it was not possible to find a suitable site for a test (ground properties, railway and suitable access).
- An installation method has been developed and tested successfully by Keller.
- SBB hope to conduct further tests after completion of the project.

Summary

- Trenches are potentially beneficial for problem sites with a soft upper soil layer.
- An open trench is predicted to have a good performance if it cuts through the soft upper soil layer.
- A soft barrier has a reduced performance but can still be attractive.
- The performance varies considerably between sites so it is essential that design calculations are made using accurate soil information.

Thank you for your attention