Innovative solutions to tyre/road noise problems: the noise and modular road surface pilots

Ard Kuijpers
M+P Raadgevende ingenieurs bv

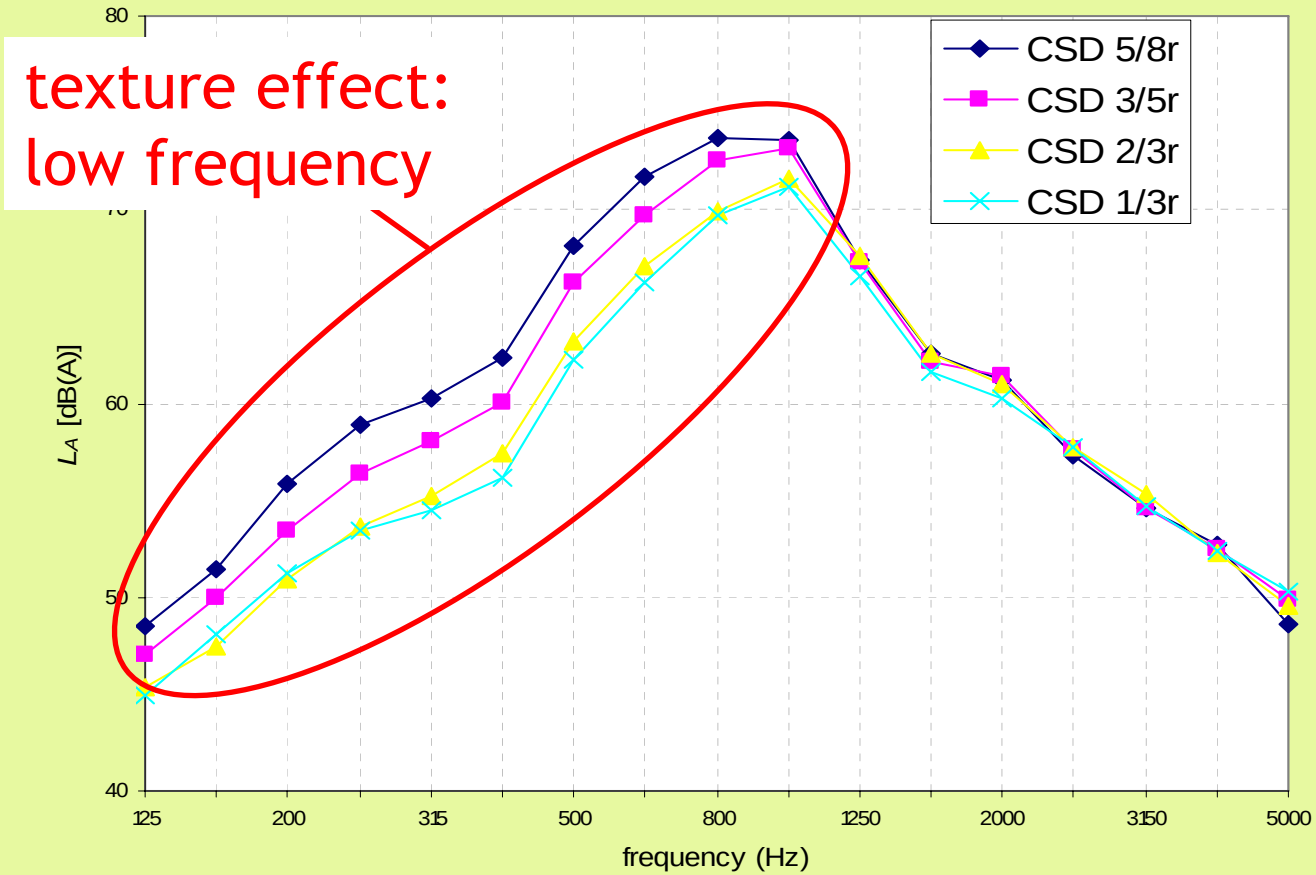
Information:
Rijkswaterstaat-DWW
M+P
Heijmans

Overview presentation

- Tyre/road noise: sperenberg insights
- Pilot: modular road surface
- Focus: uitrolbare weg
- Concept
- Design
- Construction
- Results
- Conclusions

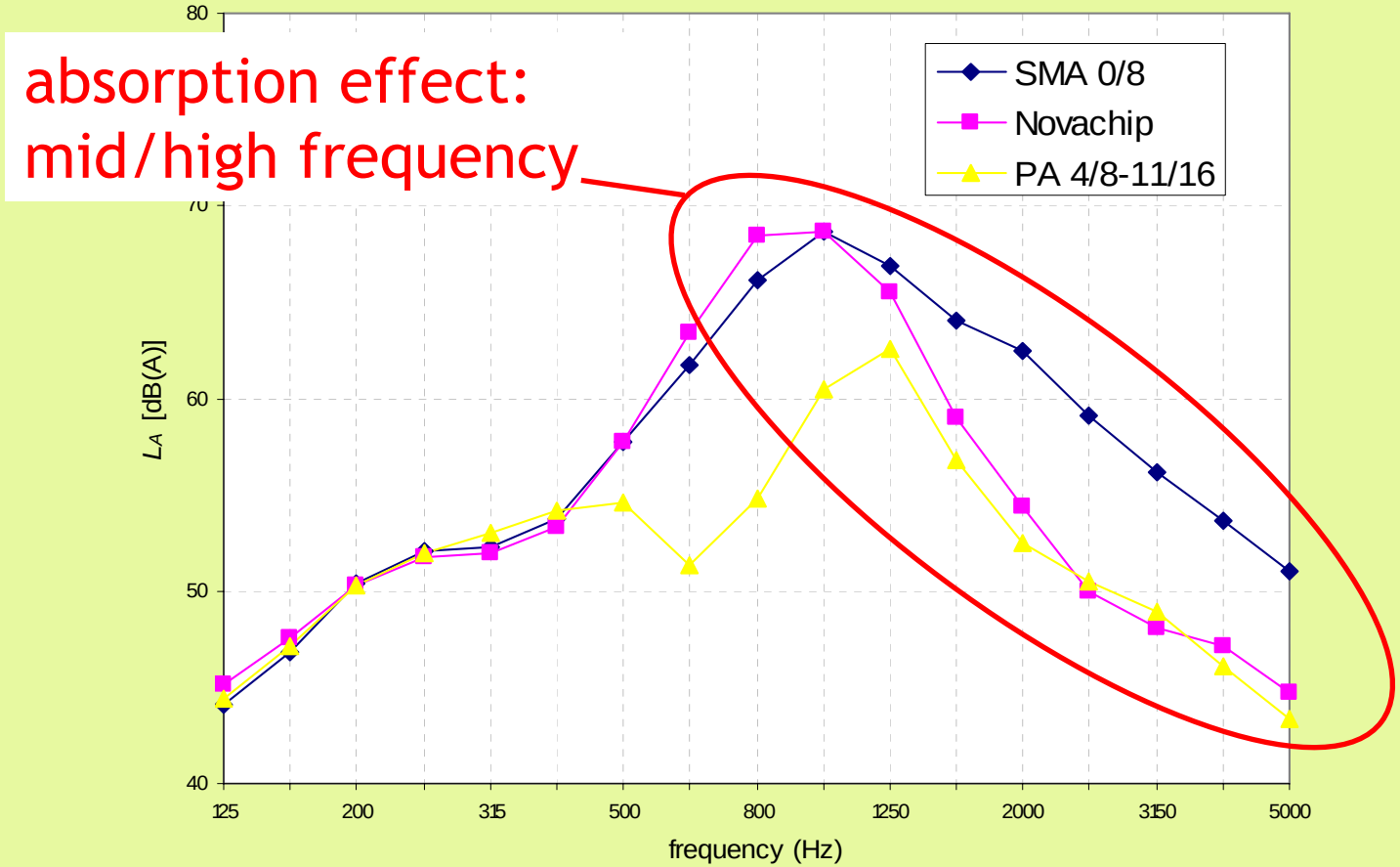
Sperenberg insights: texture

Concrete roads with different stone gradings



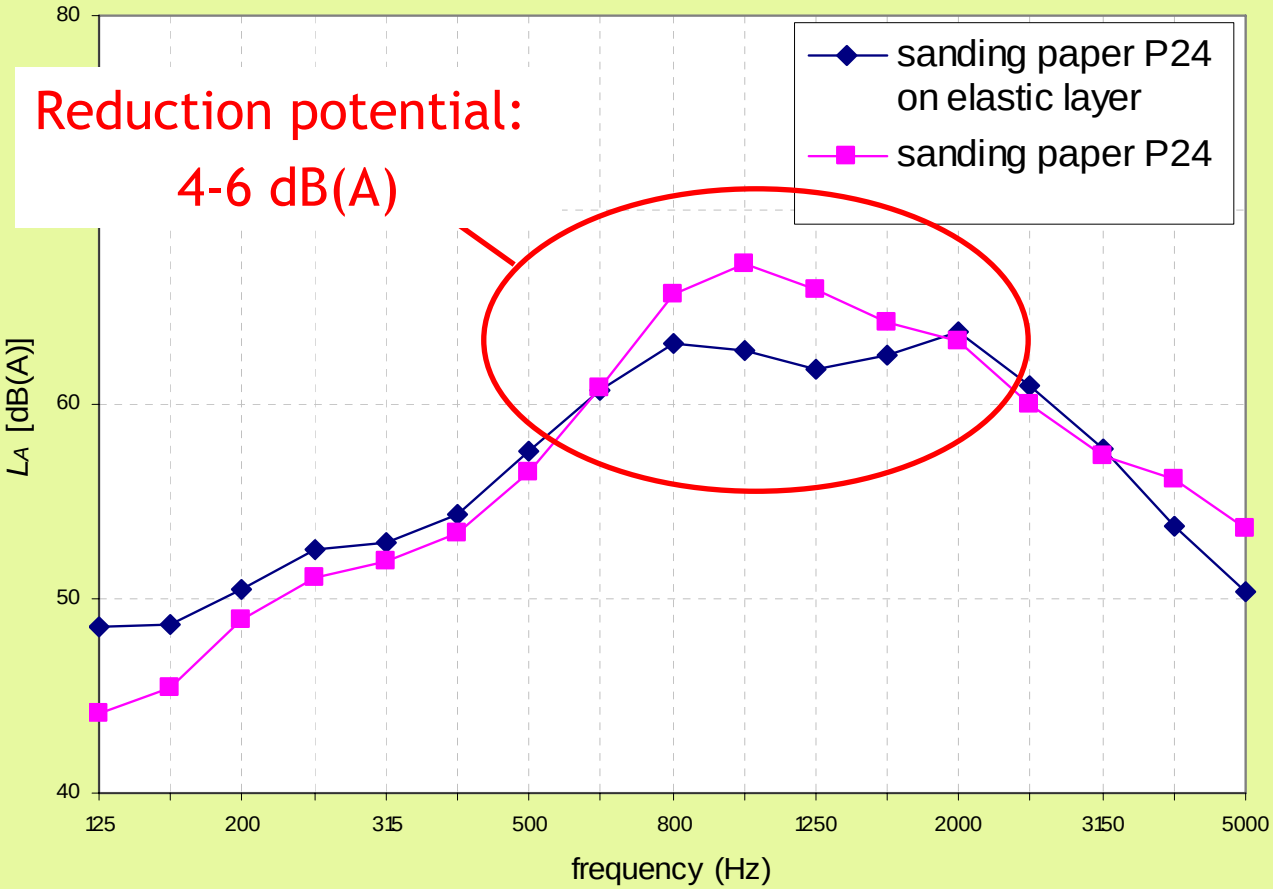
Sperenberg insights: absorption

Concrete roads with porosity

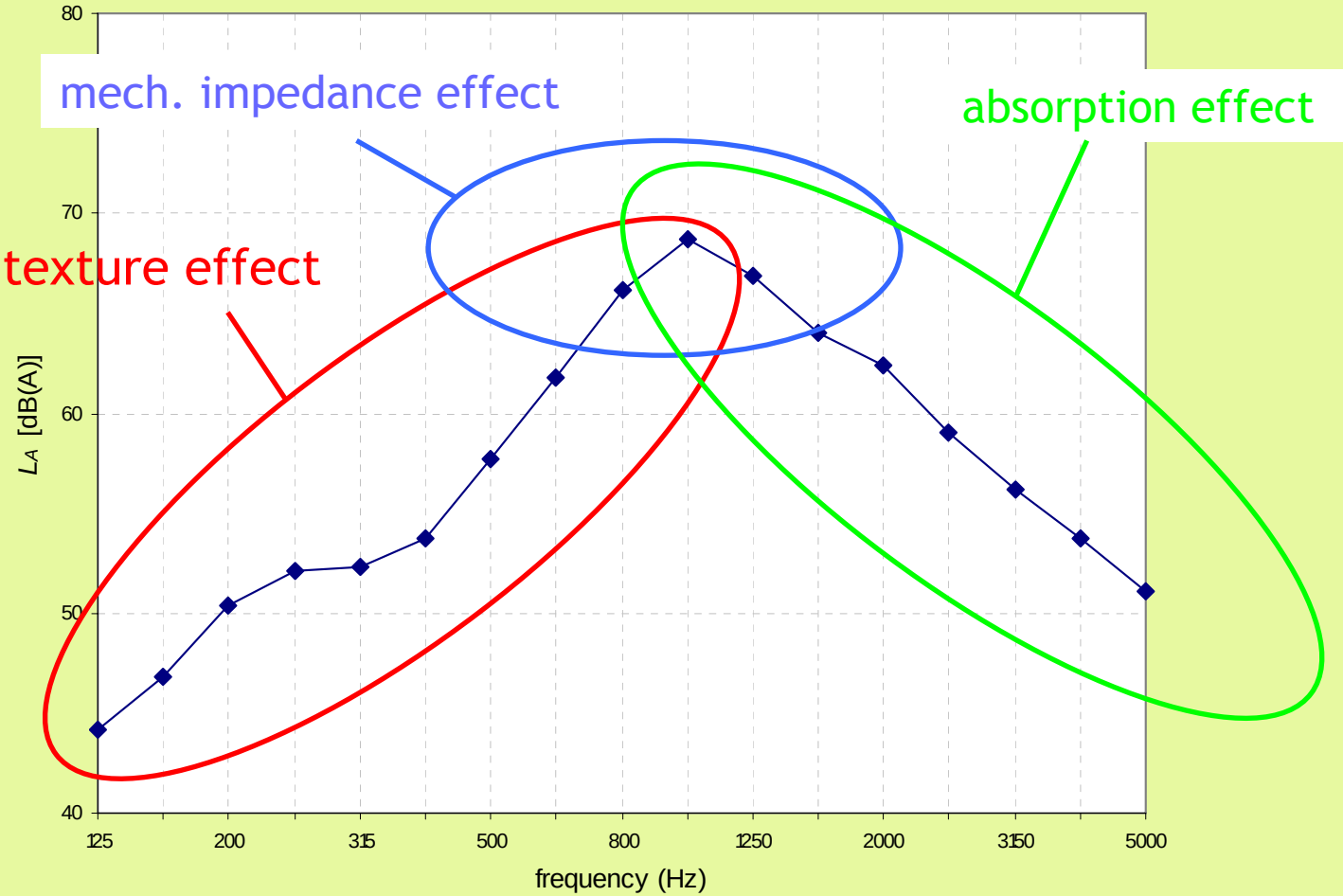


Sperenberg insights: mechanical impedance

Road with very fine texture, with/without elasitic layer



Sperenberg insights: summary



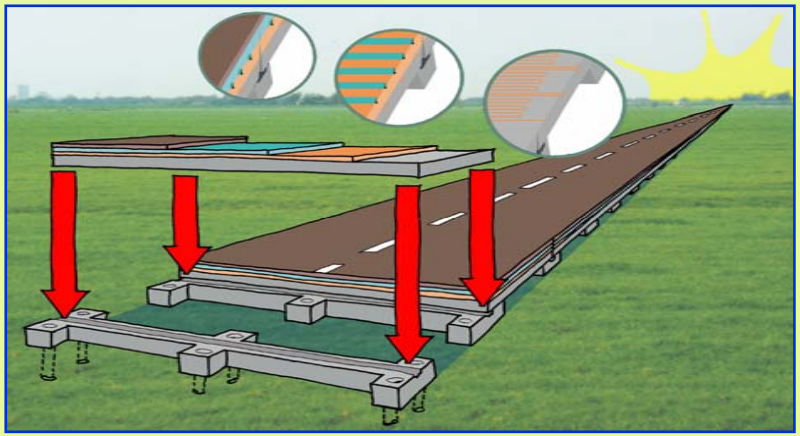
Pilot modular road surface

Contest of the Dutch Road Authority (DWW):

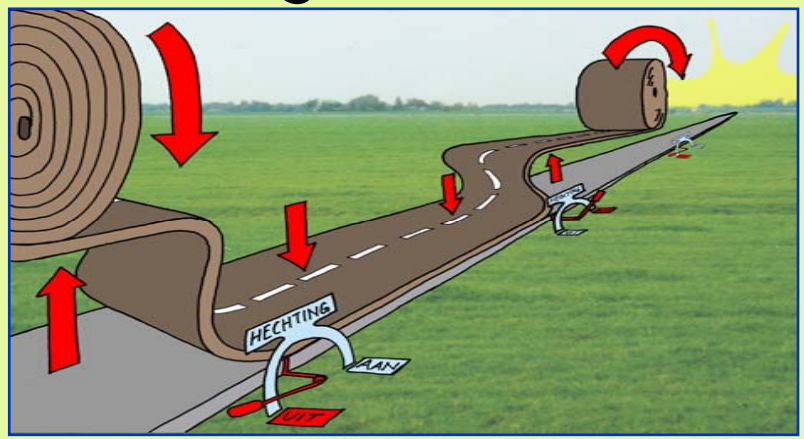
- Modular
- Easy to lay
- Good durability
- Very low noise

Contestants

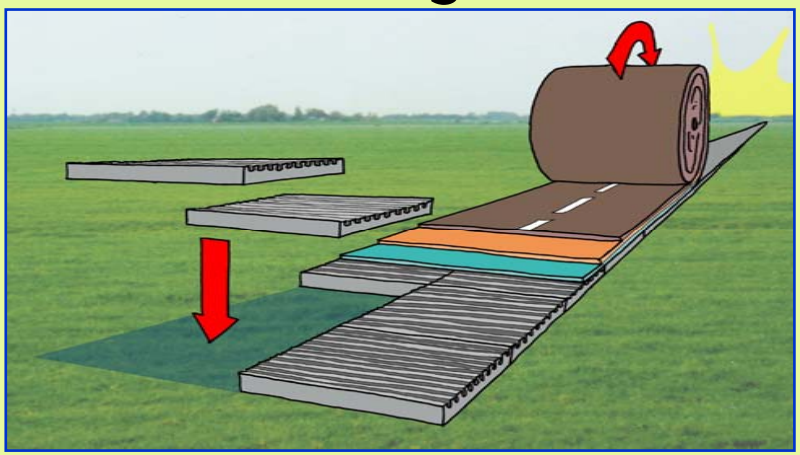
ModieSlab



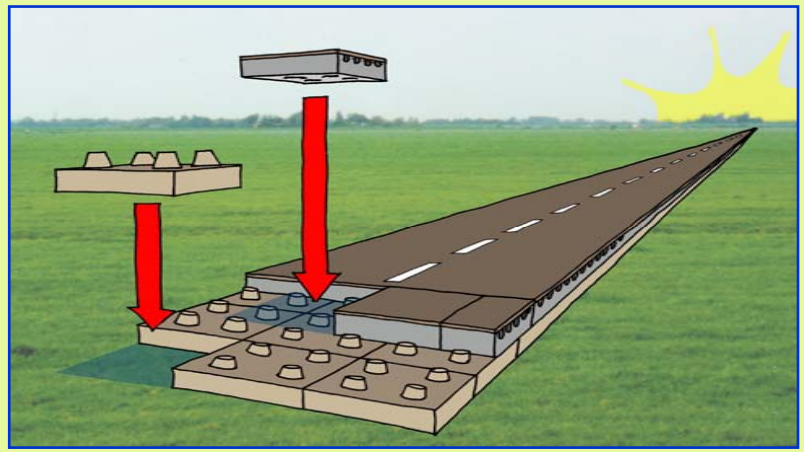
Hechtweg



Uitrolbare Weg



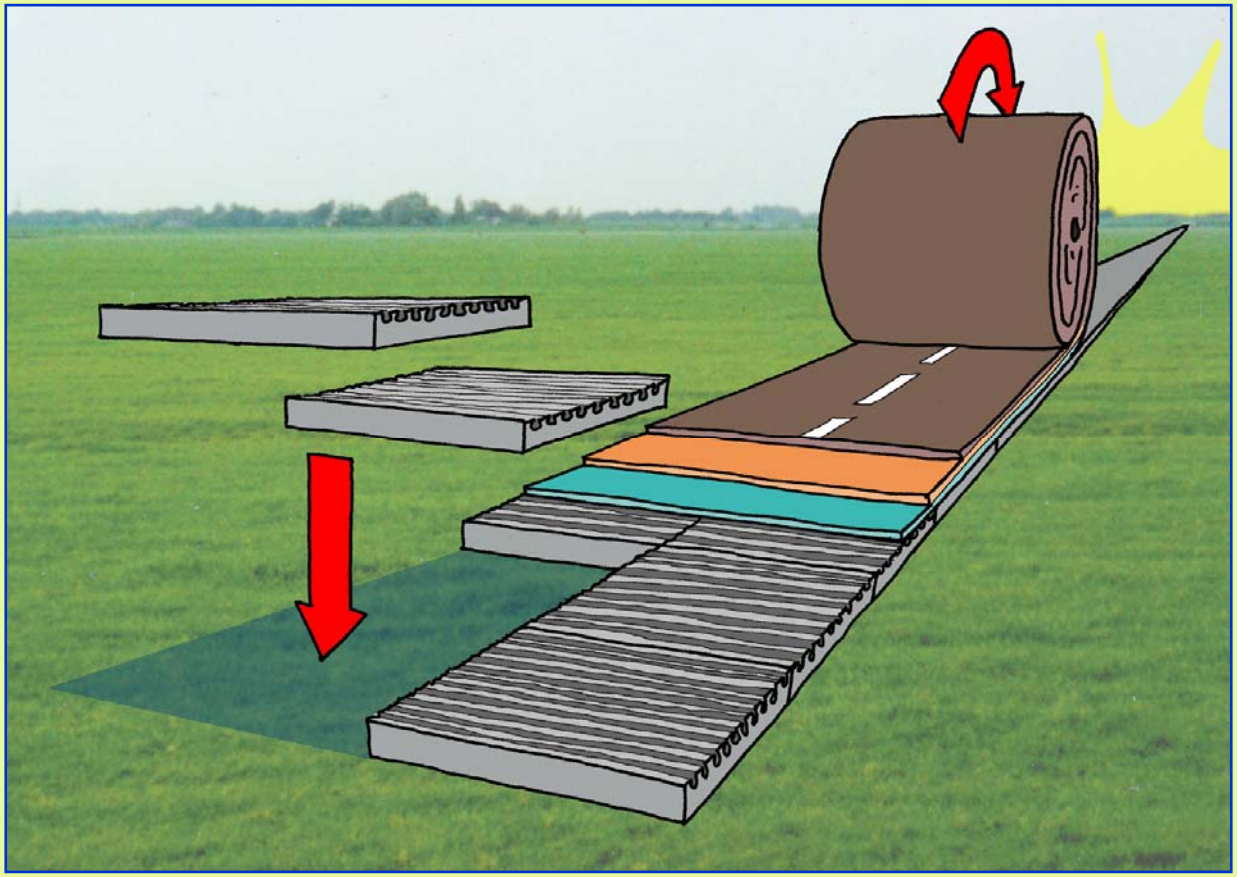
Zeer Stille Geluidsmodule



Low noise designs

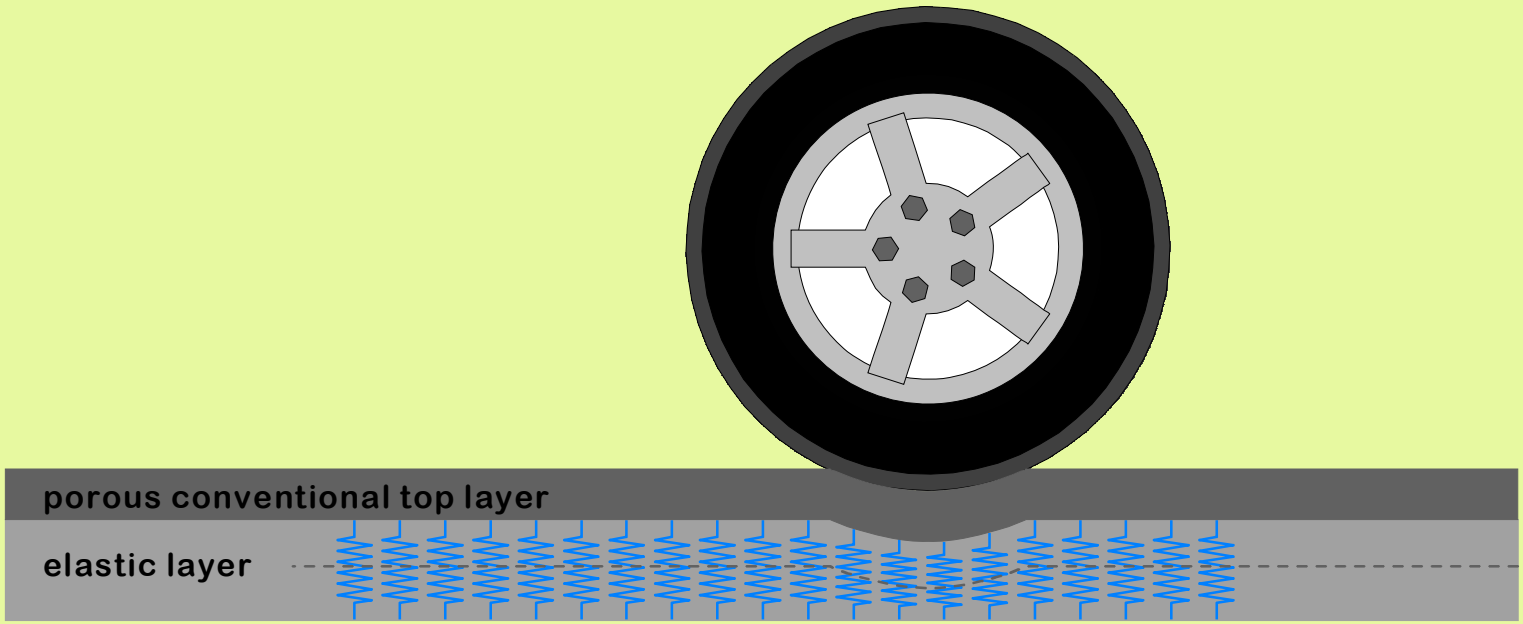
- low vibration excitation
  - Optimized texture (ModieSlab, Uitrolbare weg)
  - Mechanical impedance: (Uitrolbare weg)
- good absorption
  - Porous (All)
  - Wide absorption peaks (Uitrolbare weg, Zeer Stille Geluidsmodule)
  - Absorption optimized for vehicle types (ModieSlab)

Presentation focus: uitrolbare weg



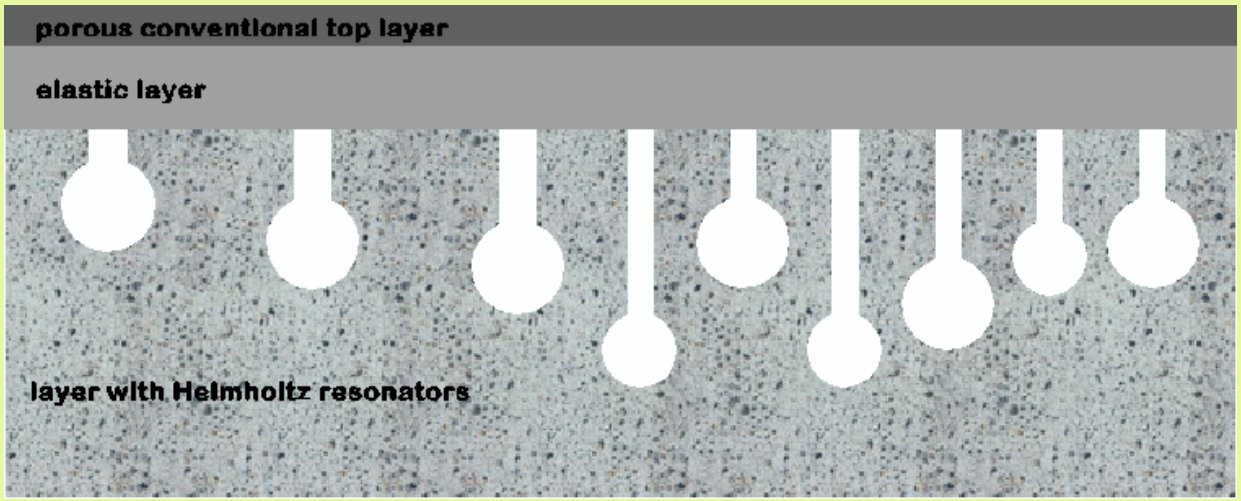
Concept: low vibration solutions

- Use 2 layer concept: fine stones upper layer
- Upside-down production in factory = supersmooth texture
- Mechanical impedance: rubber granules in 2nd layer
- Durability: elasticity in 2nd layer



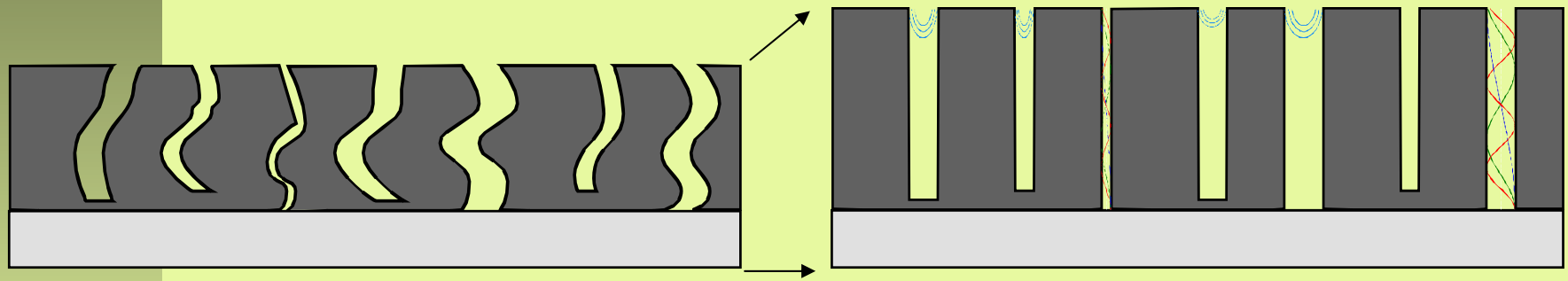
Concept: optimized absorption

- Porous top layers
- Bottom layer of Helmholtz resonators to broaden absorption spectrum

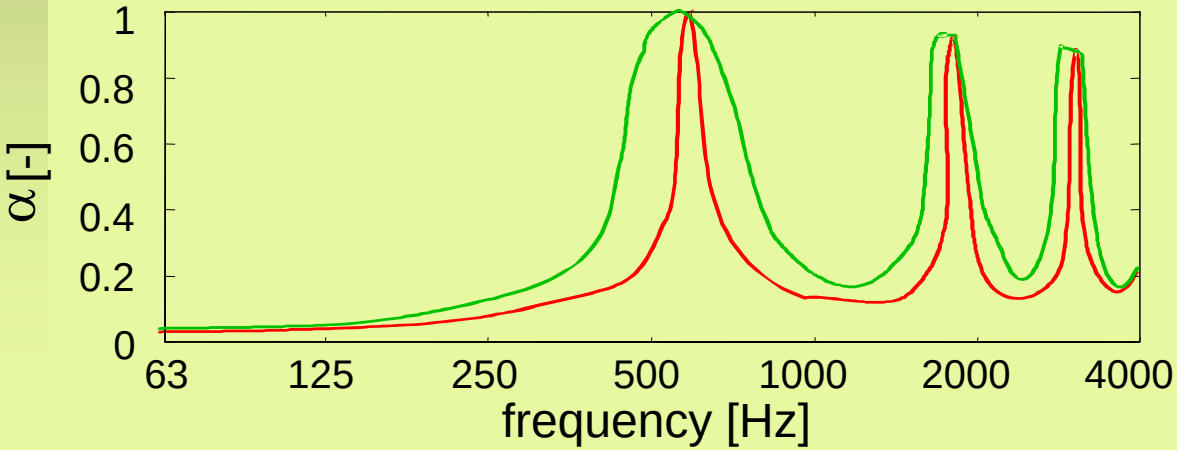


Top layer design

- Porous road surface
- Granulate forms channels in road surface
- Channels act as pipe resonators

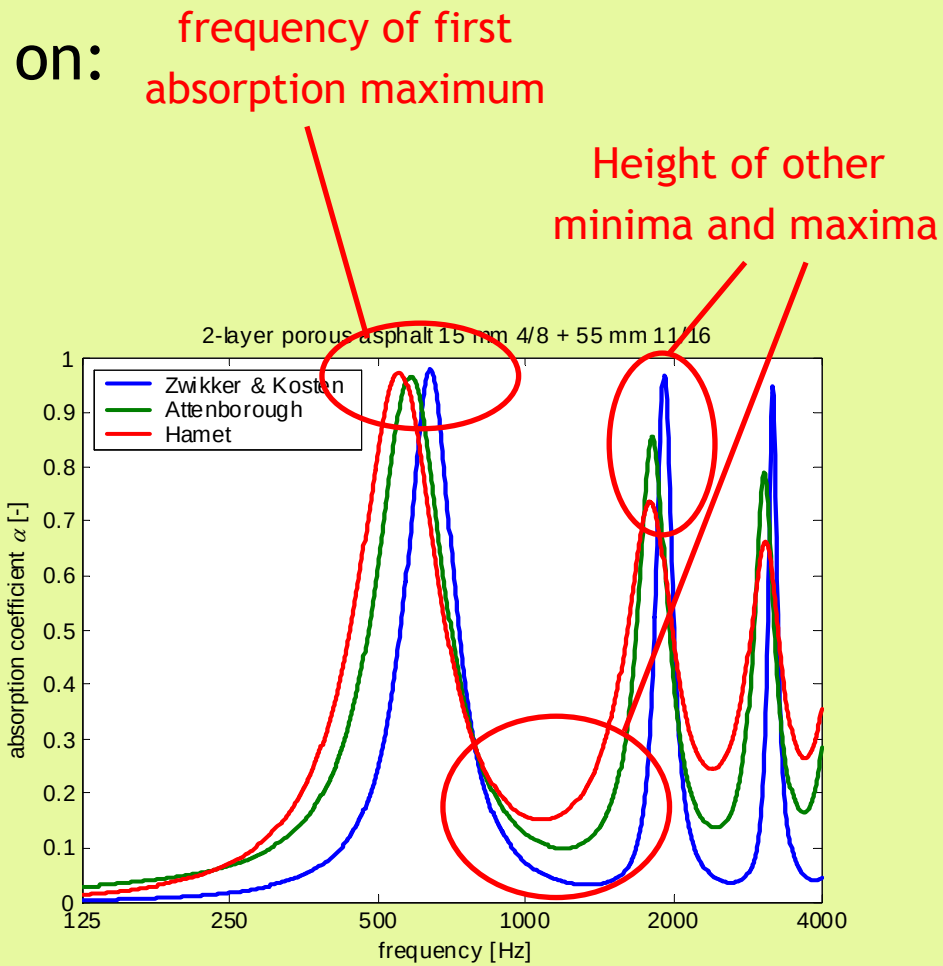


- Variation in pipe geometry: peak spread

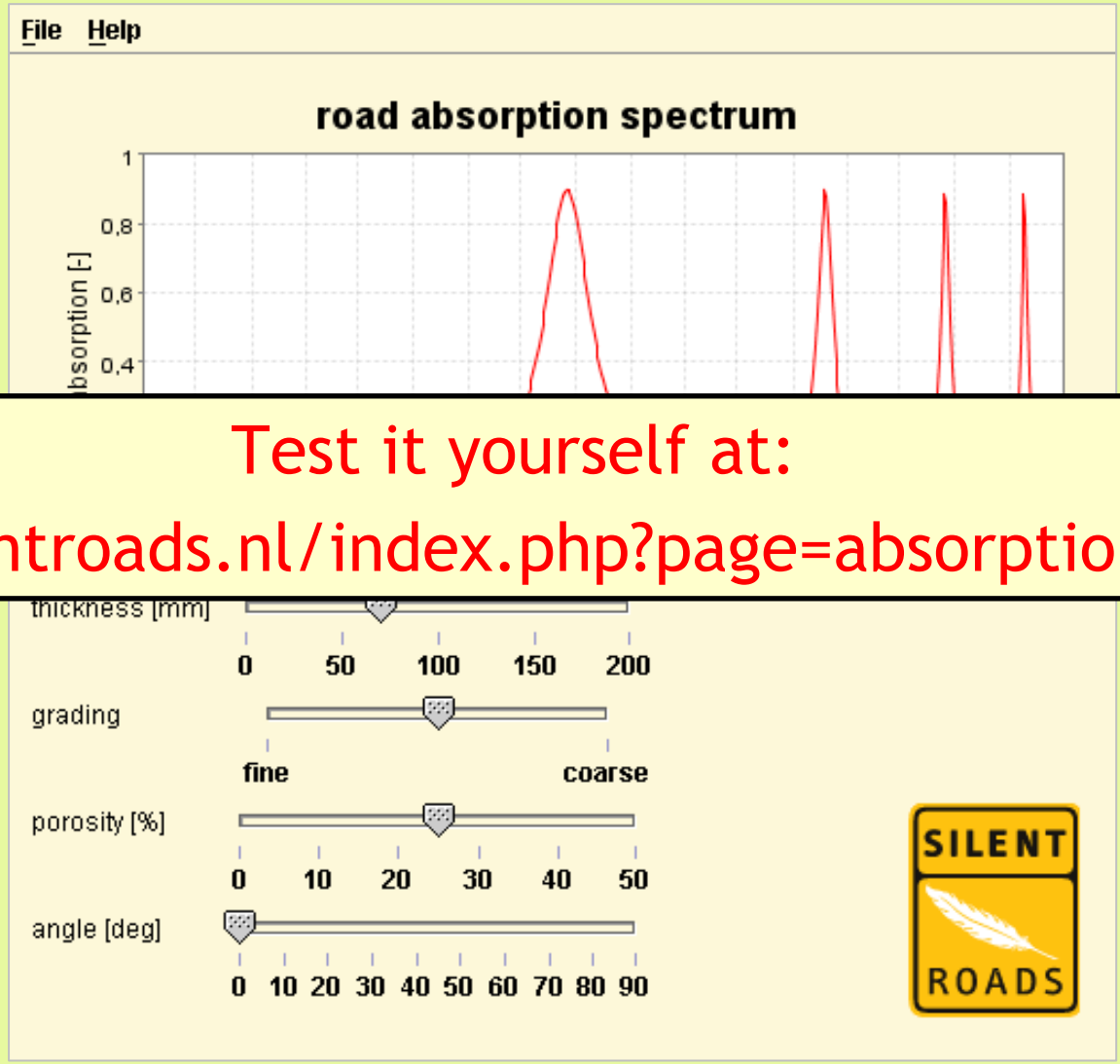


Absorption models for granular material

- Microstructural model
- Absorption depends on:
  - layer thinkness
  - porosity
  - tortuosity
  - flow resistance
  - frequency (implicit)
- Multi layer model
- Model developers
  - Zwikker & Kosten
  - Hamet
  - Attenborough

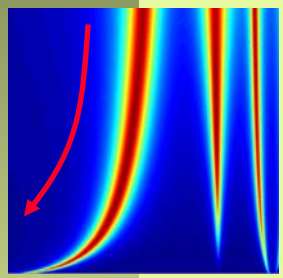


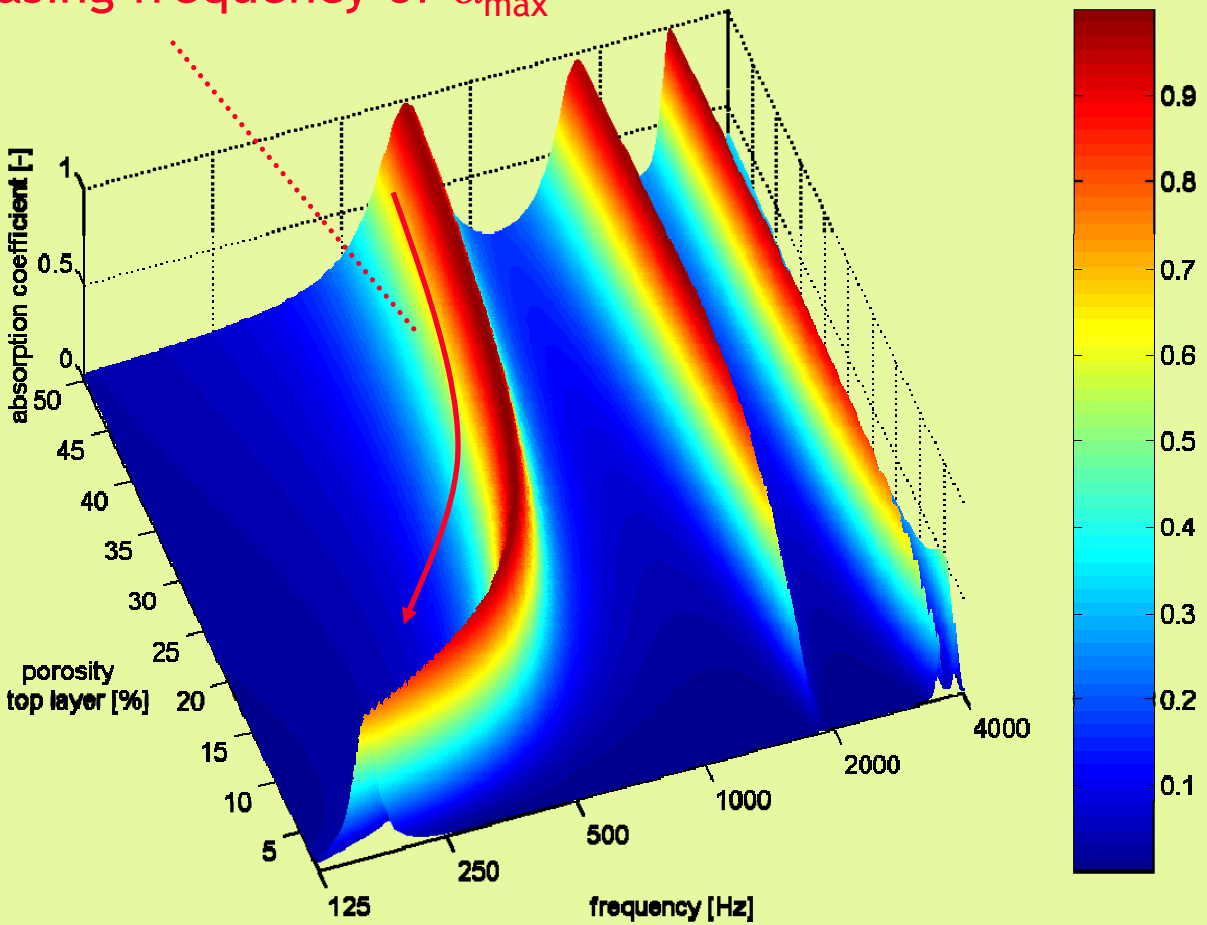
Absorption model software



Example analysis: porosity of top layer

decreasing porosity $\Rightarrow$
decreasing frequency of α_{max}





Pro's & con's of granular absorption

Advantages top layer design:

- "Proven" technology
- Absorption models fit with measurements

Disadvantages:

- Little room for optimisation
- Only absorption at pipe resonance harmonic frequencies (¼λ, ¾ λ, etc.)
- Low frequency absorption only with very thick layers

Solution?: add Helmholtz resonators

Helmholtz resonator design

- Helmholtz resonator layer:
  layer with equivalent complex acoustic impedance
- Imaginary part impedance follows from analytical expression
- Real part impedance fitted with measurements

$$\text{porosity} : \Omega = \frac{n \cdot A_{\text{resonators}}}{A_{\text{total}}}$$

- Helmholtz resonators with different impedances:

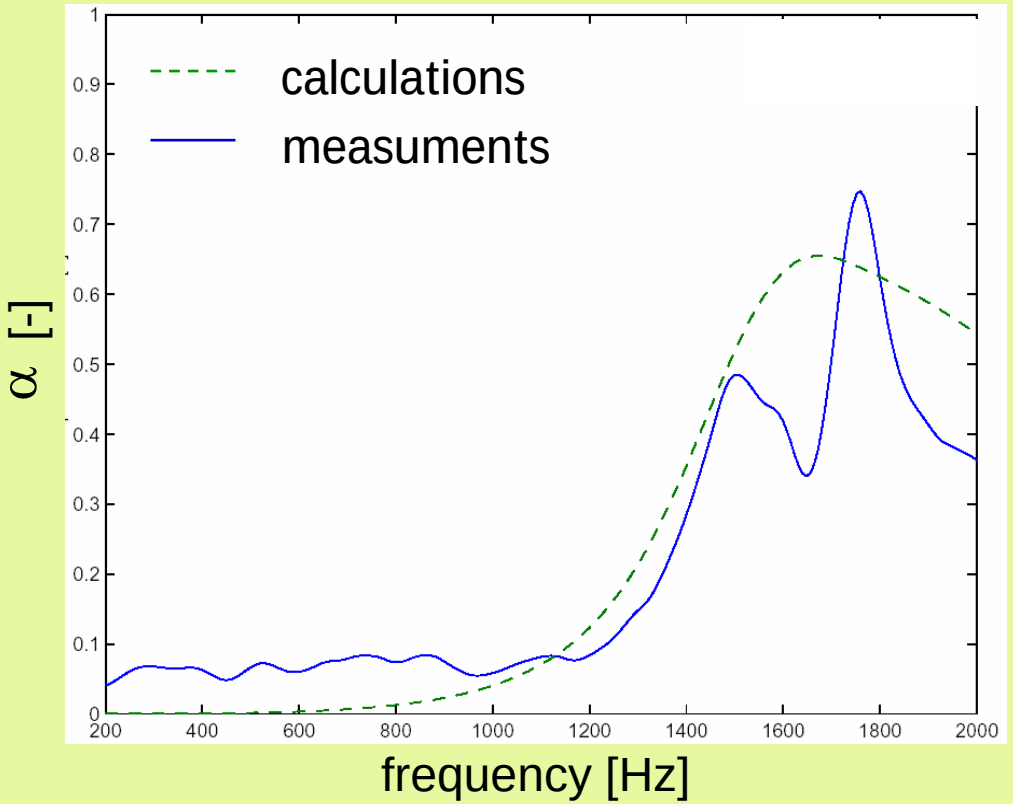
$$Z_{\text{total,layer}} = \left(\sum_{i}^{n_{\text{resonators}}} \frac{\Omega_i}{Z_i} \right)^{-1}$$

Practical considerations

- Clogging of road surface is common problem
- Helmholtz resonators cannot be “bottles”
- Slit Helmholtz resonators
- Plane wave approximation: valid/invalid?

Laboratory test: impedance tube

Model vs. measurements



Conclusion: model sufficiently accurate

Model improvements

- Adding granular top layer: model and experiments are not similar
- Impedance of Helmholtz resonators not independent of top layers (unlike granular layers)
- Solution: end-correction for neck length

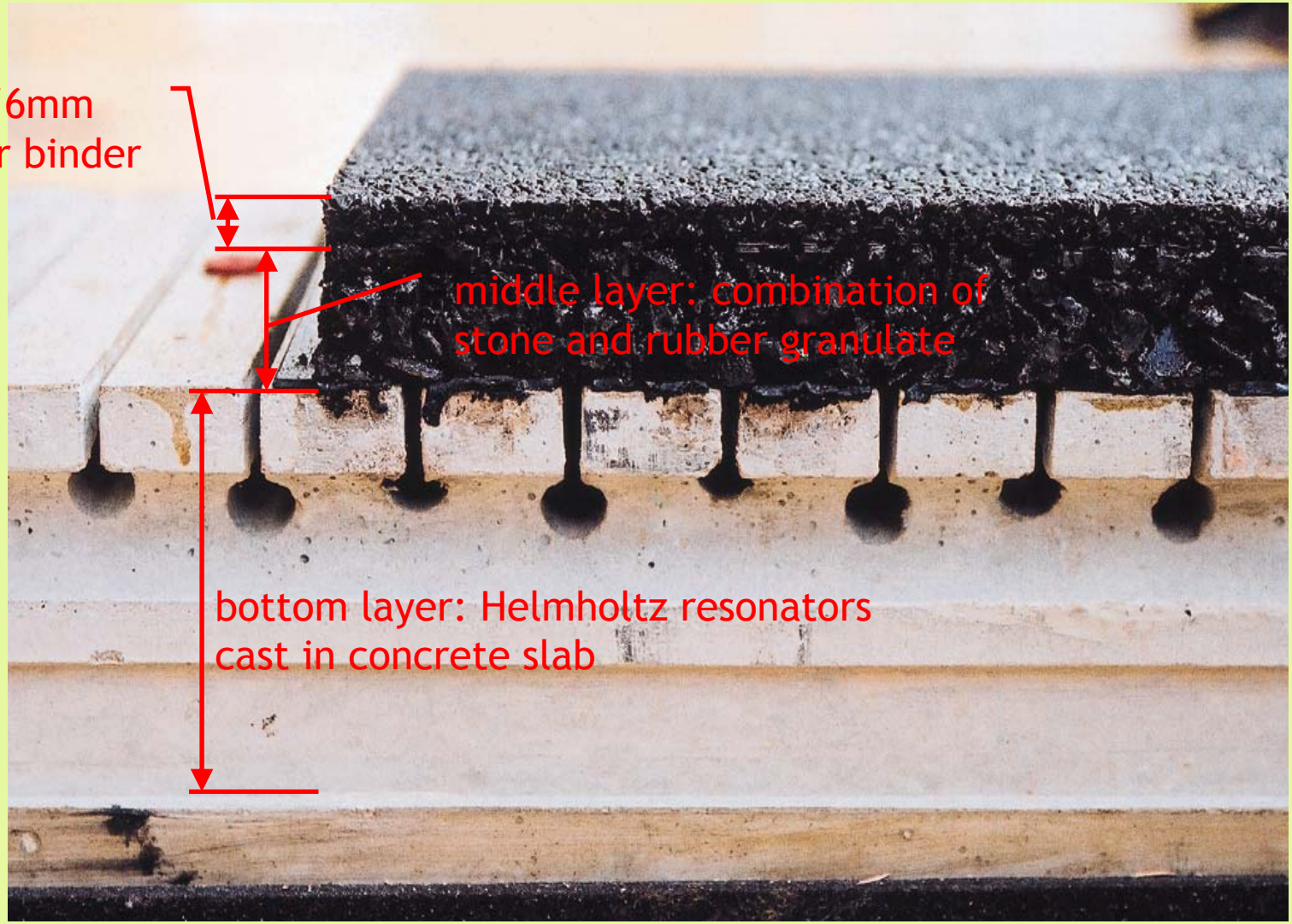
Middle layer design: mechanical impedance

Dimensioning mechanical impedance

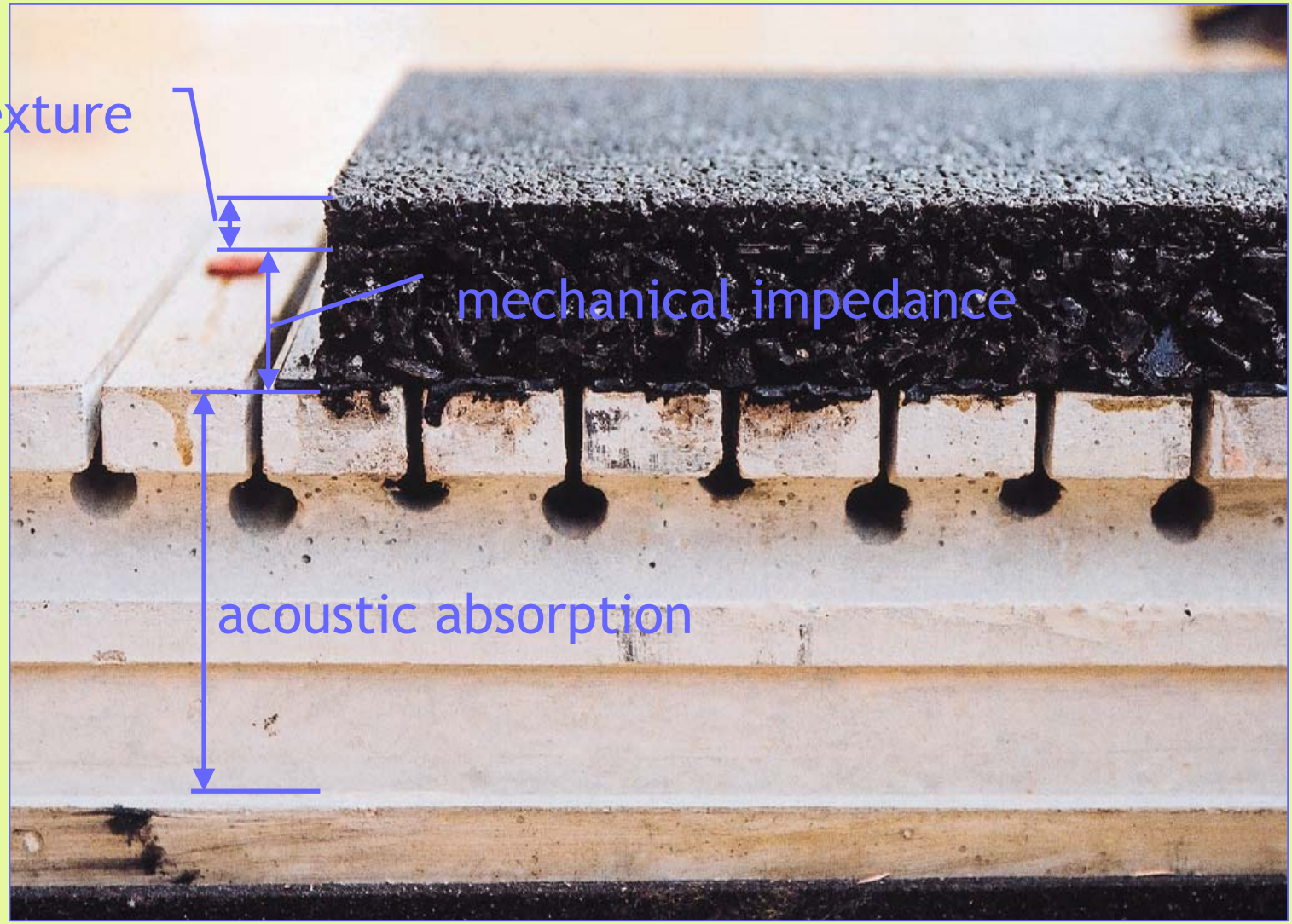
- Appropriate acoustic measurement method not available
- Dynamic “impact” test with Clegg hammer

Modular implementation

top layer: 3/6mm
with polymer binder



Modular implementation



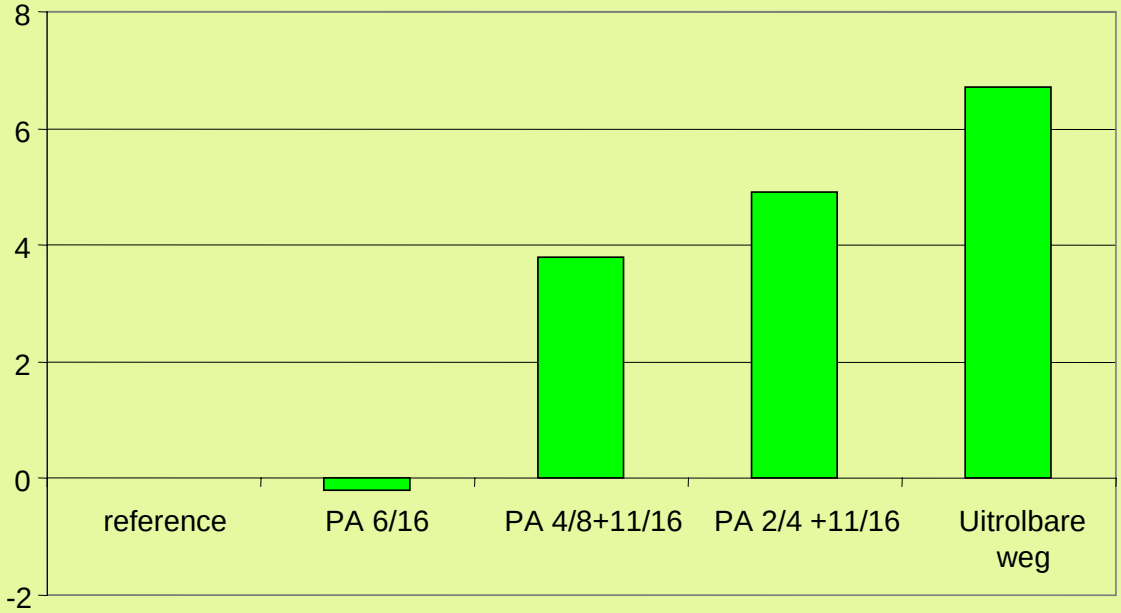
Construction

Construction

End result

Evaluation: mechanical impedance effect

- Noise reduction at 50 km/h
  (based on CPX-measurements)



- Mechanical impedance effective in 2nd layer

Evaluation: aborption effect

- Absorption effect of Helmholtz resonators demonstrated with CPX-measurement: 1.5-2 dB(A)
- SPB results do not confirm CPX results
- Effectiveness Helmholtz resonators unclear
- Further research/improvements wanted

Conclusions

Summary of results at 50 km/h

- Texture effect: 2 dB(A)
- Porosity effect: 2 dB(A)
- Mechanical impedance effect: 2-3 dB(A)
- Helmholtz effect: 0-1 dB(A)

- More information on:

  www.silentroads.nl