Acoustic Absorption Predictor

Version 1.0 — User Guide

alphaporous.com

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1. Introduction

The Acoustic Absorption Predictor is a free, open-access, browser-based tool for predicting the sound absorption coefficient α(f) of porous materials across a frequency range — with no software installation or account required.

The tool implements seven established acoustic models from simple empirical fits to full poroelastic theory, making it suitable for material design, experimental validation, parametric studies, and academic coursework.

1.1 Key Features

- Seven acoustic models: Delany-Bazley, Miki, JCA, JCAL (Lafarge), Biot, Zwikker-Kosten, and TMM
- Interactive frequency-resolved chart of absorption coefficient α(f)
- Automatic NRC (Noise Reduction Coefficient) at 250, 500, 1000, and 2000 Hz
- Multi-curve overlay for direct model and parameter comparison
- Transfer Matrix Method (TMM) for two-layer composite absorber simulation
- CSV export of full frequency data for post-processing in Excel or Python
- Runs entirely in the browser — no data sent to any server

1.2 Intended Users

- Acoustic engineers and researchers characterising porous absorbers
- Materials scientists developing novel composite sound absorbers
- Postgraduate students studying acoustic material modelling
- Architects and building acousticians selecting absorptive linings

2. Interface Overview

The tool is divided into three main areas visible after launching:

Area	Description
Left Sidebar	Model selector, parameter inputs, frequency range controls, and active curve list.
Main Panel	Chart view, NRC Table, and Data Table — switchable via tabs at the top.
Top Bar	Tool title and CSV Export button.

3. Quick Start

Follow these four steps to generate your first absorption curve:

> **INFO**
> This example uses the Delany-Bazley model — the simplest option, requiring only two inputs. It is a good starting point for fibrous materials like mineral wool or glass fibre.

Step 1 — Select a Model

In the left sidebar, click **Delany-Bazley**. The model description and its required parameter fields will appear below.

Step 2 — Enter Parameters

Type your values into the input fields. For Delany-Bazley you need:

- Flow Resistivity σ (e.g. 10000 $Pa \cdot s/m^2$)
- Thickness d (e.g. 50 mm)

Step 3 — Add to Chart

Click the blue **+ Add to Chart** button. A curve will appear in the main chart panel and an NRC badge will display in the top right of the chart.

Step 4 — Explore Results

Hover over the chart to read α values at any frequency. Switch to the NRC Table or Data Table tabs for numerical results.

4. Acoustic Models

The tool implements seven models grouped into three categories based on their theoretical basis:

Model	Category	Parameters	Notes
Delany-Bazley	Empirical	sigma, d	Fast, simple, fibrous materials. Valid for 0.01 < f/sigma < 1.
Miki	Empirical	sigma, d	Improved Delany-Bazley with better low-frequency accuracy.
JCA	Semi-Empirical	sigma, phi, alpha, Lambda, Lambda', d	Standard model for rigid-frame porous media.
JCAL (Lafarge)	Semi-Empirical	JCA + k'0	JCA extended with static thermal permeability.
Biot	Semi-Empirical	JCA + E, nu, eta_s	Full poroelastic — accounts for elastic frame vibration.
Zwikker-Kosten	Phenomenological	sigma, phi, alpha, r, d	Capillary tube model, good for foam-like materials.

TMM (2-layer)	Phenomenological	Two layers, any model	Chains two layers for multilayer absorber simulation.

4.1 Empirical Models

Empirical models (Delany-Bazley and Miki) are fitted to experimental data from fibrous materials. Both require only flow resistivity σ and thickness d.

> **WARNING**
> Delany-Bazley validity range: $0.01 < f/\sigma < 1$. Outside this range predictions become unreliable. Miki extends this range with improved low-frequency behaviour.

4.2 Semi-Empirical Models (JCA / JCAL / Biot)

These models describe viscous and thermal dissipation using microstructural parameters. JCA is the standard choice for rigid porous materials. JCAL adds static thermal permeability for improved low-frequency accuracy. Biot extends JCA to account for elastic frame vibration, important for soft foams and composite materials.

4.3 Phenomenological Models (Zwikker-Kosten / TMM)

The Zwikker-Kosten model treats the porous medium as a bundle of capillary tubes. It is physics-based and works well for foam-like materials. The TMM chains two material layers together, enabling simulation of multilayer absorbers.

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5. Input Parameters Reference

All values are entered in the display units shown in the interface. The tool converts internally (e.g. mm to m, µm to m) before computation.

Parameter	Unit	Used In	Typical Range	Description
Flow Resistivity sigma	Pa.s/m2	All models	5,000-50,000	Resistance to airflow. Higher = denser material.
Thickness d	mm	All models	10-200	Physical thickness of the absorber layer.
Porosity phi	-	JCA, JCAL, Biot, ZK	0.1-0.99	Fraction of open void volume. Fibrous: 0.90-0.99.
Tortuosity alpha_inf	-	JCA, JCAL, Biot, ZK	1.0-3.0	Complexity of pore pathways. Straight pores = 1.0.
Viscous Length Lambda	um	JCA, JCAL, Biot	20-300	Characteristic pore size for viscous effects.

Thermal Length Lambda'	um	JCA, JCAL, Biot	40-600	Char. pore size for thermal effects. Lambda' > Lambda.
Static Therm. Perm. k0'	x10^-11 m2	JCAL only	1-100	Low-frequency thermal permeability.
Pore Radius r	um	Zwikker-Kosten	10-200	Equivalent capillary tube radius.
Frame Modulus E	kPa	Biot only	10-10,000	Elastic stiffness of the solid skeleton.
Poisson Ratio nu	-	Biot only	0.1-0.45	Lateral strain ratio of the frame.
Frame Loss Factor eta_s	-	Biot only	0.01-0.2	Structural damping of the skeleton.

5.1 Entering Values

- Type any float value directly — decimals are fully supported in all fields.
- Use the UP/DOWN arrow keys to increment/decrement by the field's natural step (e.g. 100 for sigma, 0.5 mm for thickness, 0.01 for porosity).
- The chart updates automatically 250 ms after you stop typing.

> **INFO**
> Do not press Enter to confirm — just type or use arrow keys. The chart responds automatically.

6. Chart Panel

The chart displays the sound absorption coefficient α as a function of frequency for all active (visible) curves. The y-axis always spans 0 to 1.

6.1 Reading the Chart

- Hover the mouse over the chart to activate the crosshair tooltip showing α values for all visible curves at that frequency.
- NRC badges are shown in the top right of the chart, one per active curve.
- Each curve is drawn in a distinct colour matching its label in the Active Curves list.

6.2 Adding Multiple Curves

To add a second curve with different parameters:

- Modify the parameter values in the sidebar.
- Click **+ Add to Chart** again.
- A new curve will be added with a new colour.

You can also switch to a different model and add curves for cross-model comparison.

6.3 Managing Active Curves

- ■ **button** — toggles visibility on/off without deleting the curve.
- ✕ **button** — permanently removes the curve from the chart.

7. NRC Table

The NRC (Noise Reduction Coefficient) tab shows absorption at the four standard octave-band centre frequencies used in room acoustics:

250 Hz	500 Hz	1000 Hz	2000 Hz
Low-mid bass	Mid	Upper-mid	High-mid

$$\mathrm{NRC} = (\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}) / 4$$

The NRC is a single-number rating from 0 (fully reflective) to 1 (fully absorptive). The table includes a colour-coded performance scale:

NRC Range	Rating	Typical Application
< 0.2	Poor	Hard surfaces: concrete, glass, plaster
0.2-0.4	Fair	Thin carpet, light curtains
0.4-0.6	Good	Standard acoustic tiles, medium foam
0.6-0.8	Very Good	Thick fibrous panels, heavy curtains
> 0.8	Excellent	Specialist acoustic wedges, deep absorbers

8. Data Table and CSV Export

The Data Table tab shows the computed α value at all 200 frequency points for every visible curve.

8.1 Exporting Data

Click the **Export CSV** button to download a comma-separated file containing:

- Column 1: Frequency in Hz (rounded to nearest integer)
- Subsequent columns: α values for each visible curve to 4 decimal places

The file can be opened in Microsoft Excel, LibreOffice Calc, or imported into Python, MATLAB, or R.

> **INFO**
> Only visible curves are included in the export. Hidden curves (toggled off) are excluded.

9. Using the Transfer Matrix Method (TMM)

The TMM model simulates a two-layer absorber by chaining any two acoustic models together. Useful for composite configurations such as:

- Mineral wool backed by a foam layer
- Perforated panel facing a fibrous fill
- Two foams with different densities bonded together

9.1 Setting Up a TMM Configuration

- Select **TMM (2-layer)** in the model list.
- Two layer panels appear — Layer 1 and Layer 2.
- Use the dropdown in each panel to select the model for that layer.
- Enter parameters for each layer independently.
- Click **+ Add to Chart** to compute the combined response.

> **IMPORTANT — LAYER ORDER**
> Layer 1 is the face layer (sound incidence side). Layer 2 is the backing layer. The rigid backing wall is assumed at the end of Layer 2.

10. Frequency Range Settings

The frequency range is controlled by the **Min (Hz)** and **Max (Hz)** inputs in the sidebar. Default range is 100-5000 Hz.

10.1 Axis Scale

- **Log scale** (default) — recommended for acoustics; aligns with octave band analysis.
- **Linear scale** — useful for visualising narrow-band resonance peaks in detail.

> **INFO**
> 200 frequency points are always computed regardless of range, so narrowing the range increases resolution within that band.

11. Tips and Best Practices

11.1 Comparing Models

To compare predictions from different models for the same material, add each model as a separate curve with the same parameters. The chart overlays them automatically.

11.2 Parametric Studies

To study the effect of a single parameter (e.g. thickness), add multiple curves with the same σ but different d values. This is a common technique for optimising panel thickness for a target NRC.

11.3 Matching Experimental Data

If you have measured impedance tube data, export a matching prediction from the tool as CSV and overlay them in Excel to assess model accuracy for your material.

11.4 Choosing the Right Model

- Fibrous materials (glass wool, mineral wool): Start with Miki or Delany-Bazley.
- Open-cell foam, ceramic foam: Use JCA or JCAL.
- Soft foam (elastic skeleton): Use Biot — set E_frame and eta_s appropriately.
- Layered composite: Use TMM with appropriate models per layer.
- Unknown material: Run all models with the same σ and compare — the spread indicates sensitivity.

12. How to Cite

If you use this tool in research or publications, please cite it as follows:

APA

Olajide, J. L. (2026). *Acoustic Absorption Predictor: A browser-based tool for porous material acoustic modelling* [Web application]. University of South Africa (UNISA), Department of Mechanical, Bioresources and Biomedical Engineering. https://alphaporous.com

BibTeX

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@misc{olajide2026acoustictool,
  author = {Olajide, Jimmy Lolu},
  title = {Acoustic Absorption Predictor},
  year = {2026},
  note = {https://alphaporous.com},
}
```

13. Technical Notes

Standard air properties at 20°C used for all calculations:

- Air density rho0 = 1.213 kg/m^3
- Speed of sound c0 = 343 m/s
- Characteristic impedance Z0 = rho0 x c0 = 415.86 Pa.s/m

- Dynamic viscosity eta = 1.84×10^{-5} Pa.s
- Ambient pressure P0 = 101,325 Pa
- Heat capacity ratio gamma = 1.4
- Prandtl number Pr = 0.711

All models assume normal sound incidence onto a material layer backed by a rigid, perfectly reflecting wall. The absorption coefficient α is computed from the surface impedance Z_s as:

$$R = (Z_s/Z_0 - 1) / (Z_s/Z_0 + 1) \qquad \alpha = 1 - |R|^2$$

All complex arithmetic is implemented in pure JavaScript with no external dependencies. The tool runs entirely client-side; no parameter data is ever transmitted to a server.

14. References

The following publications form the theoretical basis of the models implemented in this tool:

Allard, J. F., & Atalla, N. (2009). *Propagation of sound in porous media: Modelling sound absorbing materials* (2nd ed.). John Wiley & Sons. https://doi.org/10.1002/9780470747339

Biot, M. A. (1956). Theory of propagation of elastic waves in a fluid-saturated porous solid. I. Low-frequency range. *Journal of the Acoustical Society of America, 28*(2), 168–178. https://doi.org/10.1121/1.1908239

Champoux, Y., & Allard, J. F. (1991). Dynamic tortuosity and bulk modulus in air-saturated porous media. *Journal of Applied Physics, 70*(4), 1975–1979. https://doi.org/10.1063/1.349482

Delany, M. E., & Bazley, E. N. (1970). Acoustical properties of fibrous absorbent materials. *Applied Acoustics, 3*(2), 105–116. https://doi.org/10.1016/0003-682X(70)90031-9

Johnson, D. L., Koplik, J., & Dashen, R. (1987). Theory of dynamic permeability and tortuosity in fluid-saturated porous media. *Journal of Fluid Mechanics, 176*, 379–402. https://doi.org/10.1017/S0022112087000727

Lafarge, D., Lemarinier, P., Allard, J. F., & Tarnow, V. (1997). Dynamic compressibility of air in porous structures at audible frequencies. *Journal of the Acoustical Society of America, 102*(4), 1995–2006. https://doi.org/10.1121/1.419690

Miki, Y. (1990). Acoustical properties of porous materials — modifications of Delany-Bazley models. *Journal of the Acoustical Society of Japan (E), 11*(1), 19–24. https://doi.org/10.1250/ast.11.19

Olajide, J. L. (2026). *Acoustic Absorption Predictor: A browser-based tool for porous material acoustic modelling* [Web application]. University of South Africa (UNISA), Department of Mechanical, Bioresources and Biomedical Engineering. https://alphaporous.com

Zwikker, C., & Kosten, C. W. (1949). *Sound absorbing materials*. Elsevier Publishing Company.

15. Glossary

Key terms used throughout this guide and in the acoustic materials literature:

Absorption Coefficient (α)

A dimensionless value between 0 and 1 representing the fraction of incident sound energy absorbed by a material at a given frequency. $\alpha = 0$ means perfect reflection; $\alpha = 1$ means perfect absorption.

Airflow Resistivity (σ)

A measure of how strongly a porous material resists steady airflow through it, expressed in $Pa \cdot s/m^2$. Higher values indicate denser, more resistive materials. Typical fibrous materials range from 5,000 to 50,000 $Pa \cdot s/m^2$.

Characteristic Viscous Length (Λ)

A microstructural parameter representing the effective pore radius controlling viscous momentum transfer between the fluid and solid frame. Used in JCA, JCAL, and Biot models. Typically smaller than the thermal characteristic length.

Characteristic Thermal Length (Λ')

A microstructural parameter representing the effective pore radius controlling thermal energy exchange between the fluid and solid frame. Always larger than the viscous characteristic length ($\Lambda' > \Lambda$). Used in JCA, JCAL, and Biot models.

Frame Loss Factor (η_s)

A dimensionless coefficient quantifying the structural (viscoelastic) damping of the solid skeleton in a poroelastic material. Used in the Biot model. Typical values range from 0.01 to 0.2.

Frame Modulus (E)

The elastic (Young's) modulus of the solid skeleton of a porous material, expressed in kPa. It characterises the stiffness of the frame and is used in the Biot model to account for frame vibration contributions to sound absorption.

Impedance

The ratio of acoustic pressure to particle velocity at a surface, expressed in Pa·s/m (or Rayl). The characteristic impedance of air Z■ = ρ■c■ ≈ 416 Pa·s/m. Surface impedance determines the absorption coefficient through the reflection coefficient formula.

NRC — Noise Reduction Coefficient

A single-number rating of a material's sound absorption performance, calculated as the arithmetic mean of absorption coefficients at 250, 500, 1000, and 2000 Hz. Values range from 0 (fully reflective) to 1 (fully absorptive). Standardised per ASTM C423.

Normal Incidence

The assumption that sound waves strike the material surface perpendicularly (at 0° angle). All models in this tool assume normal incidence with a rigid backing wall. Random-incidence absorption (measured in a reverberant room) typically yields higher NRC values.

Poisson's Ratio (ν)

A dimensionless elastic constant describing the ratio of lateral strain to axial strain in the solid frame. Values range from 0 to 0.5 for most materials. Used in the Biot model.

Poroelastic Material

A material consisting of a solid elastic skeleton saturated with a fluid (air). Both the fluid and the solid frame can vibrate and contribute to sound absorption. The Biot model is the standard framework for poroelastic acoustic modelling.

Porosity (ϕ)

The fraction of the total material volume occupied by open, interconnected pores through which fluid can flow. Expressed as a dimensionless value between 0 and 1. Typical fibrous materials have ϕ = 0.90–0.99; rigid foams may have ϕ = 0.60–0.95.

Rigid-Frame Assumption

A simplifying assumption that the solid skeleton of a porous material does not vibrate — only the fluid moves. Valid when the frame is stiff relative to the fluid. Used in Delany-Bazley, Miki, JCA, JCAL, and Zwikker-Kosten models. The Biot model relaxes this assumption.

Static Thermal Permeability (k'■)

A low-frequency parameter used in the JCAL model to improve accuracy of thermal dissipation prediction. Expressed in units of 10■^{11} m^2. Typical values range from 1 to 100 × 10■^{11} m^2.

Tortuosity (α_∞)

A dimensionless microstructural parameter describing the complexity and curvature of pore pathways relative to the macroscopic propagation direction. Straight, parallel pores give α_∞ = 1.0. Tortuous, winding pores give α_∞ > 1. Typical values: 1.0–3.0.

Transfer Matrix Method (TMM)

A mathematical framework for computing the acoustic response of layered systems by representing each layer as a 2×2 matrix relating pressure and velocity across its thickness. Matrices are multiplied in sequence to obtain the overall system response.

Viscous Skin Depth

The characteristic thickness of the viscous boundary layer in a pore at a given frequency, defined as δ = √(2η/ρ■ω). At low frequencies the viscous layer fills the pore; at high frequencies it is confined to the pore walls.