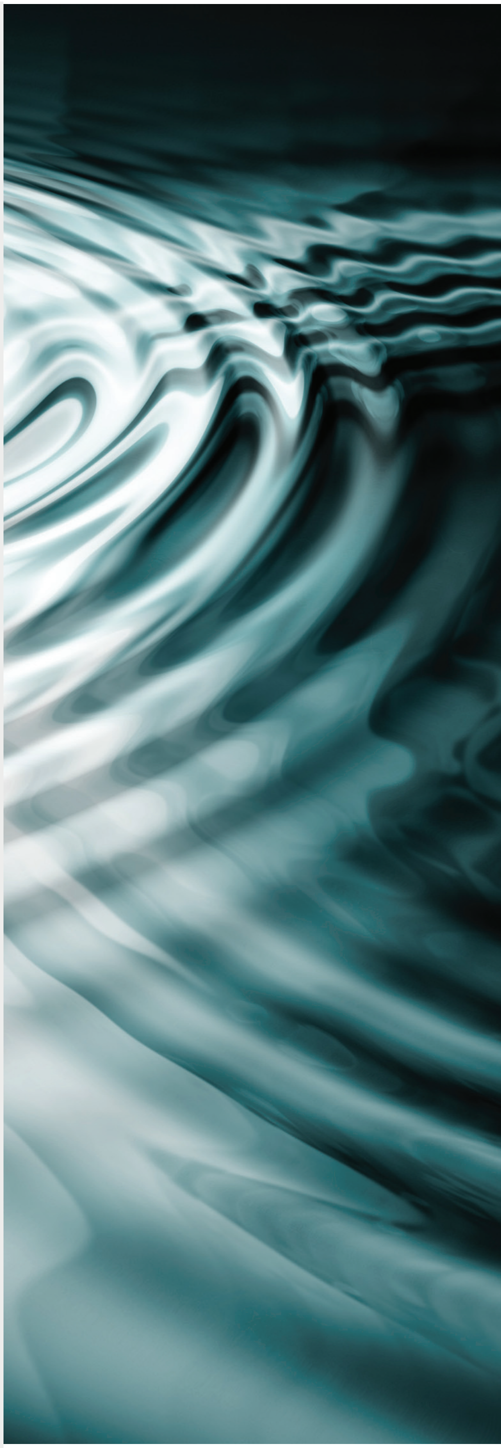
Materials Design:
Understanding Load Versus Natural Frequency Curves



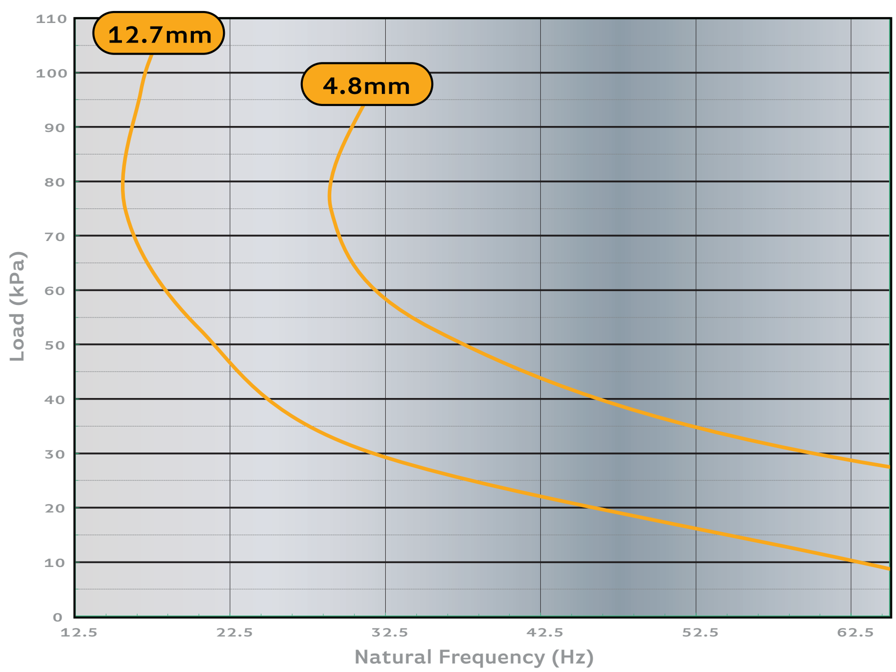
Understanding how to compare
the overabundance of materials designed for vibration management in today's marketplace is challenging. There are several materials that can perform vibration isolation, but not all materials are high performance. Bubble wrap, for example, will do a great job at isolating vibrations if used correctly, but it is not a durable product and will ultimately fail. Bubble wrap is an extreme example, but engineers have identified that bubble wrap is an effective way to prevent damage from products in shipping but not necessarily applicable for vibration mounts.

To select the right material, engineers must understand the physical properties required in the application, including temperature range, expected service life, safety factors, and regulatory specifications. Material options then need to be compared with respect to vibration isolation.

Two curves are found in the majority of vibration data sheets. Understanding how to read each curve and knowing how they are generated enables engineers to design effective solutions.

The first curve, Load versus Natural frequency, helps engineers identify the material with the lowest natural frequency. The second curve, Vibration Isolation Efficiency, takes the design one step further by comparing materials to identify which product has a larger region of isolation.

Both Load vs. Natural Frequency and Vibration Isolation Efficiency are derived from Material Characterization testing often referred to as Transmissibility Testing. Additional information on this testing can be found in MATERIALS DESIGN: Vibration Isolation and Damping, The Basics on the Rogers Website.



Load vs. Natural Frequency

When designing for isolation, engineers tend to look for materials with a low natural frequency.

Figure 1.0
Rogers' PORON® 4701-50-15 material load vs. natural frequency curve for 12.7mm (0.500") and 4.8 mm (0.188") thicknesses

Load vs. Natural Frequency Curve

This curve illustrates how the natural frequency of a material changes based on material thickness and the load applied. Load vs. Natural Frequency aids engineers in determining what the material's natural frequency will be in the end application. Using a Single Degree of Freedom (SDOF) system, we can define natural frequency as a function of mass and stiffness.

As illustrated on the right, two variables impact natural frequency. The first is Material stiffness, k (further defined as a function of the elastic modulus and the physical shape of the sample being tested, where A is the area in contact with the load and L is the length or thickness of the sample). The second variable, m, is the mass or load being applied to the material.

The curve in Figure 1.0 shows that when thickness is increased from 4.8mm to 12.7mm the curve shifts to achieve a lower natural frequency and Equation 3.0 explains this shift. In this example, the thickness (L) was increased, changing the expected natural frequency. Increasing L 2.5 times decreased the value of k which effectively lowered the natural frequency of the material by 50%.

Another method of altering the natural frequency of the material is by changing m, the mass on the system. In many applications the load is predetermined, but distribution of the load can be changed by in-

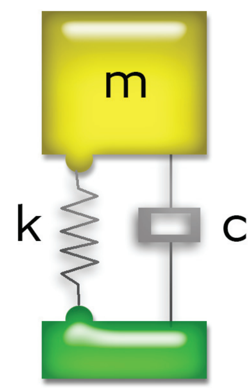


Figure 2.0
SDOF system

$$natural\ \ frequency\ (\omega) = \sqrt{k/m}$$
(Eq. 3.0)

$m = mass$
$k = stiffness$
$c = damping\ coefficient$

$$k = \frac{AE}{L}$$
(Eq. 3.1)

Equation 3.0:
Calculating a material's natural frequency

creasing or decreasing the contact area. Similarly, increasing m lowers the ratio of k/m, lowering the natural frequency.

Before the load versus natural frequency curve can be used, it must be generated. Curve generation begins when transmissibility curves are generated for a material under various loads in the system. Figure 3.0 below illustrates how this data typically appears. The natural frequency of the material decreases as additional load is applied to the system. The load is increased incrementally during testing until the material has surpassed its limit of compressibility. At this point the material's modulus of elasticity increases dramatically and the natural frequency begins to increase.

The curves in Figure 3.0 come together to form the load versus natural frequency curve in Figure 4.0 The X-axis represents the natural frequency for each of the various loads applied. The Y-axis is the Load at which the natural frequency was achieved.

The Equation shows that several factors can affect the performance of the material; modulus of elasticity, contact area, and thickness.

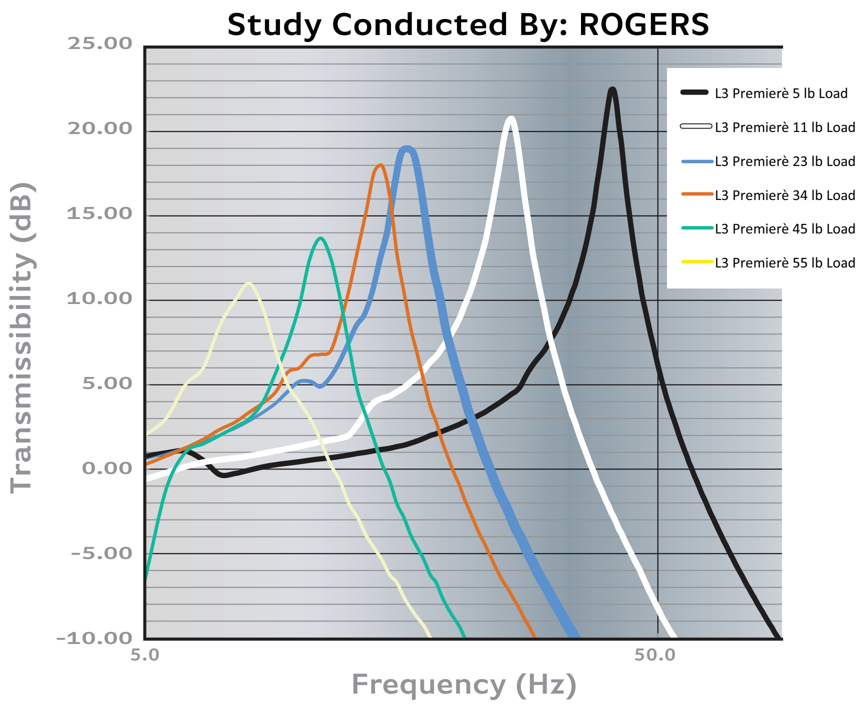


Figure 3.0
Rogers' BISCO® L3-Premiere Transmissibility Curve at various Loads

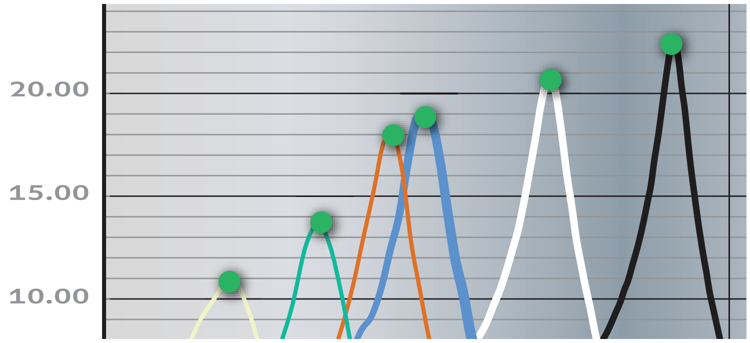


Figure 3.1
Enlarged section of Graph in Figure 3.0

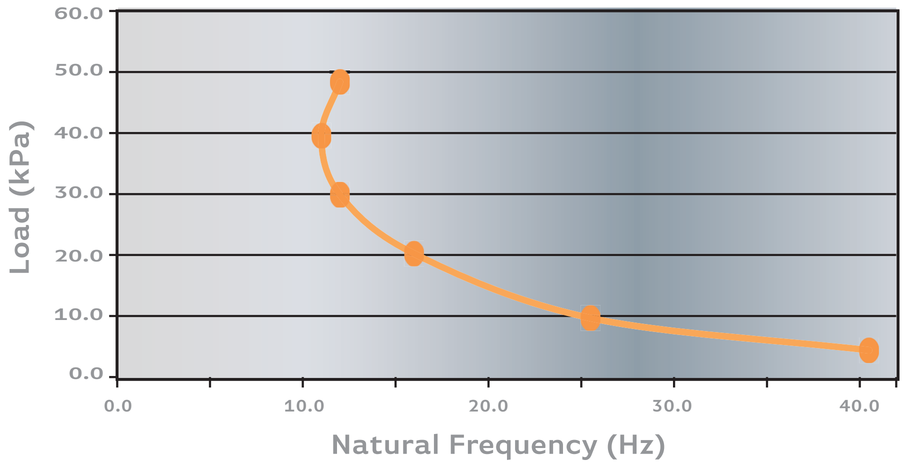


Figure 4.0
Data Points Translated into Load versus Natural Frequency Curve.

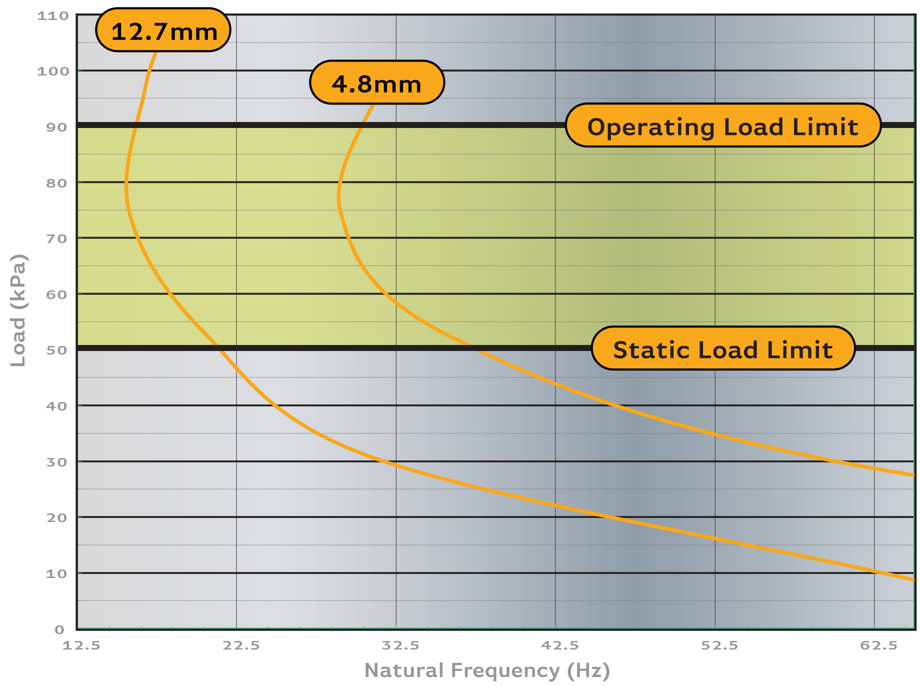


Figure 5.0
Operating Range of Rogers' PORON®

Operating Range

Some data sheets also provide operating ranges. The operating range is the recommended loading that will yield the optimum performance. Figure 5.0 above shows the operating range of the material centered around the lowest natural frequency of the product.

Understanding and using the load versus natural frequency curve is step one of a two-step process for selecting an appropriate material. The second step is to understand and use the vibration isolation efficiency curve in MATERIALS DESIGN: Understanding Vibration Isolation Efficiency Curves.

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