Quarterly meeting technical presentation:

Mechanical Properties of Elastomeric Vibration Isolators

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Introduction

- **Ryan Arbabi** CEng BSc (Hons) MIOA
  - Technical Director at Farrat UK
  - One of less than 200 Chartered Acoustic Engineers in the world
  - 10+ years of experience
  - Member of the Institute of Acoustics Editorial Board
  - Secretary of the UK Groundborne Vibration Working Group
  - STEM Ambassador

- Farrat
  - Vibration Isolation
    - Materials Science
    - Mechanical Engineering
    - Structural Engineering
    - Acoustic Engineering and Dynamics
    - Construction Engineering / Industry Focused
  - Building Isolation
  - High Performance Sound Insulation

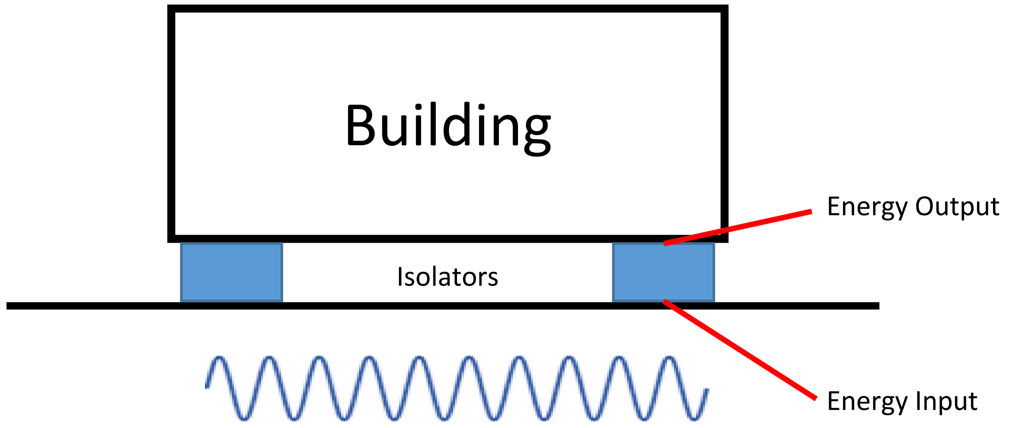
Summary

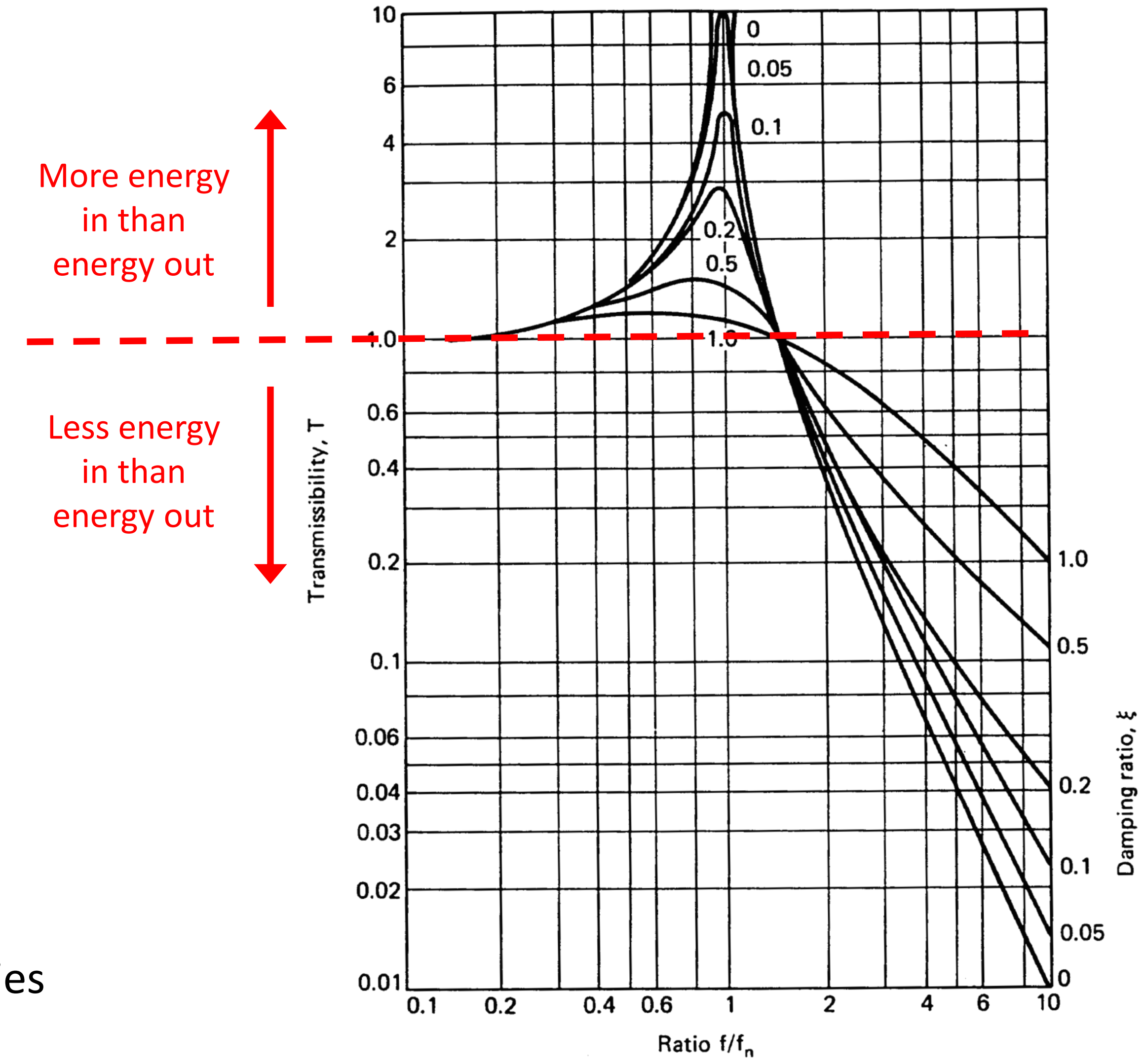
- Acoustic Terminology
- Isolator Properties
- Practical Examples
- Why is this Important?

Transmissibility

- The ratio of energy output to energy output

- In the context of a vibration isolator:

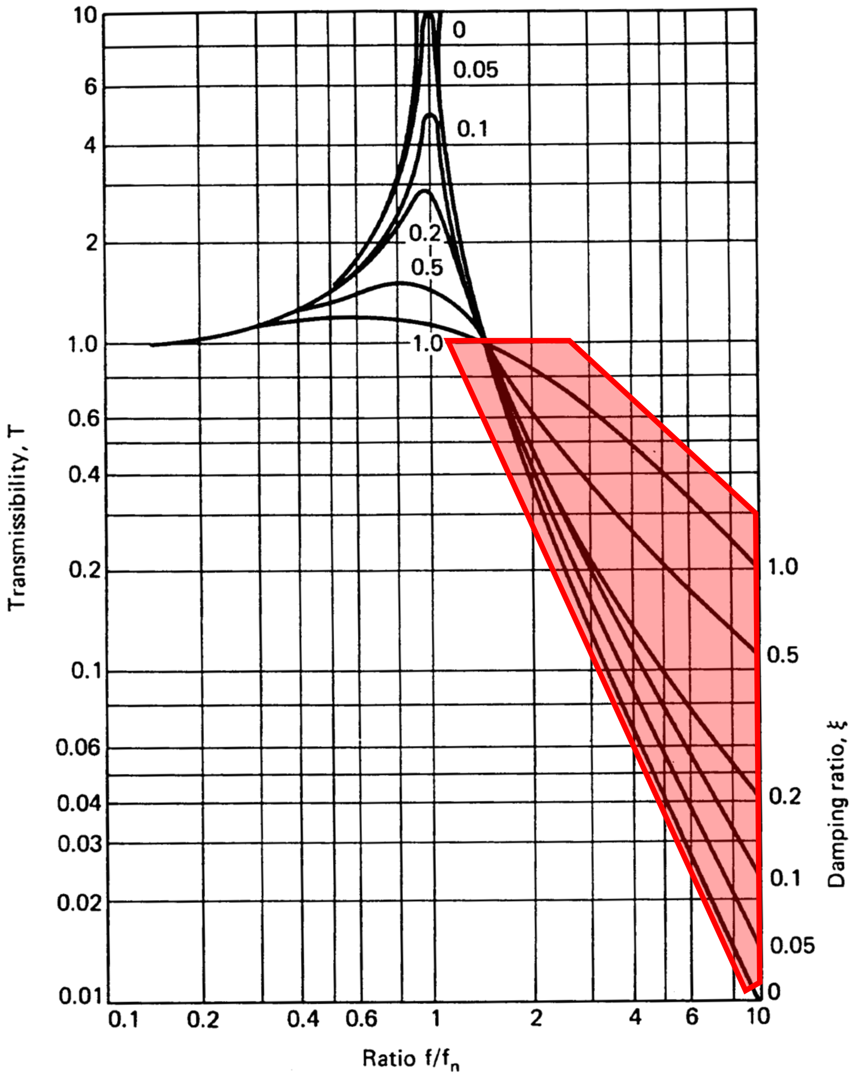




- Energy isn’t created. It is drawn from nearby frequencies

Isolation

- The vibrational energy output (at a given frequency) is less than the energy supplied
- Amplification occurs when there is more vibrational energy (at a given frequency) than is supplied
- The reduction of the magnitude of vibration is caused by:
  - Mechanical work = heat
  - Decoupling the system (impedance mismatching)
  - Energy is rearranged so that the inertia opposes the force



Resonance

- Every material has a natural frequency (f_n) with associated harmonics
- Structures contain multiple natural frequencies & harmonics
  - The lowest or "**fundamental**" natural frequency has the most energy
  - **Harmonics** have lower energy but can coincide with structural natural frequencies
    - Walking = 2Hz – Harmonics at: 4Hz, 8Hz etc.
- **Resonance** occurs when the disturbing frequency (f_e)

  = f_n (the natural frequency) of the supporting structure

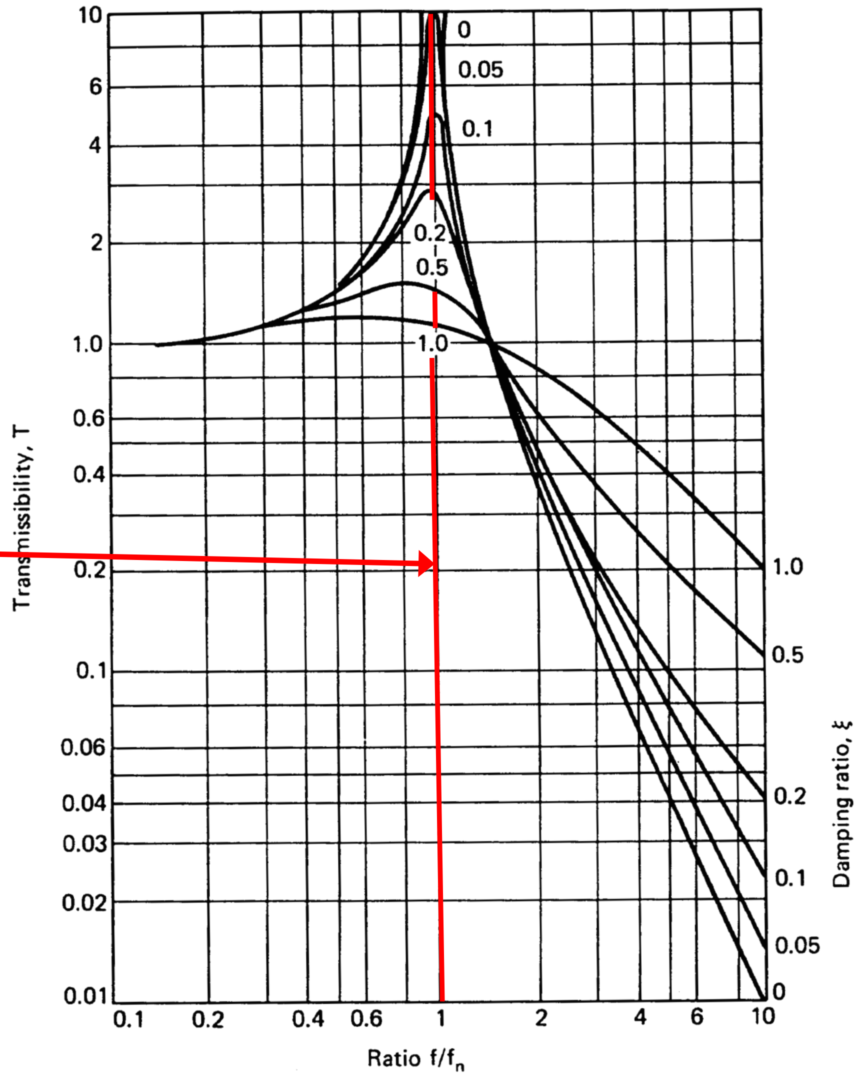
  i.e. ratio of $f_e / f_n = 1$
- **Transmissibility** > 1 = ↑ transmitted vibration (and possibly amplified)
- **Tuning** can eliminate resonance amplification by changing a system's

  f_n so that it ≠ f_e

Mass: f_n is proportional to the stiffness divided by the mass

2 x mass = ½ x vibration

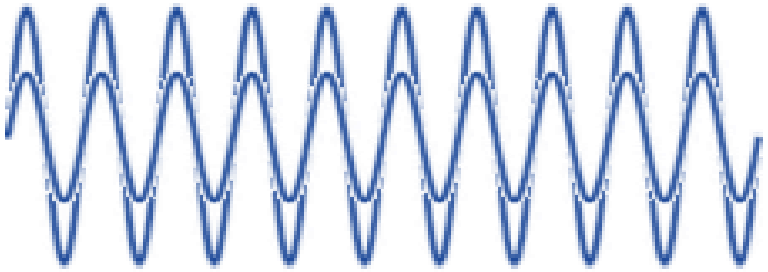
Stiffness: Stiffening a part will ↑ f_n



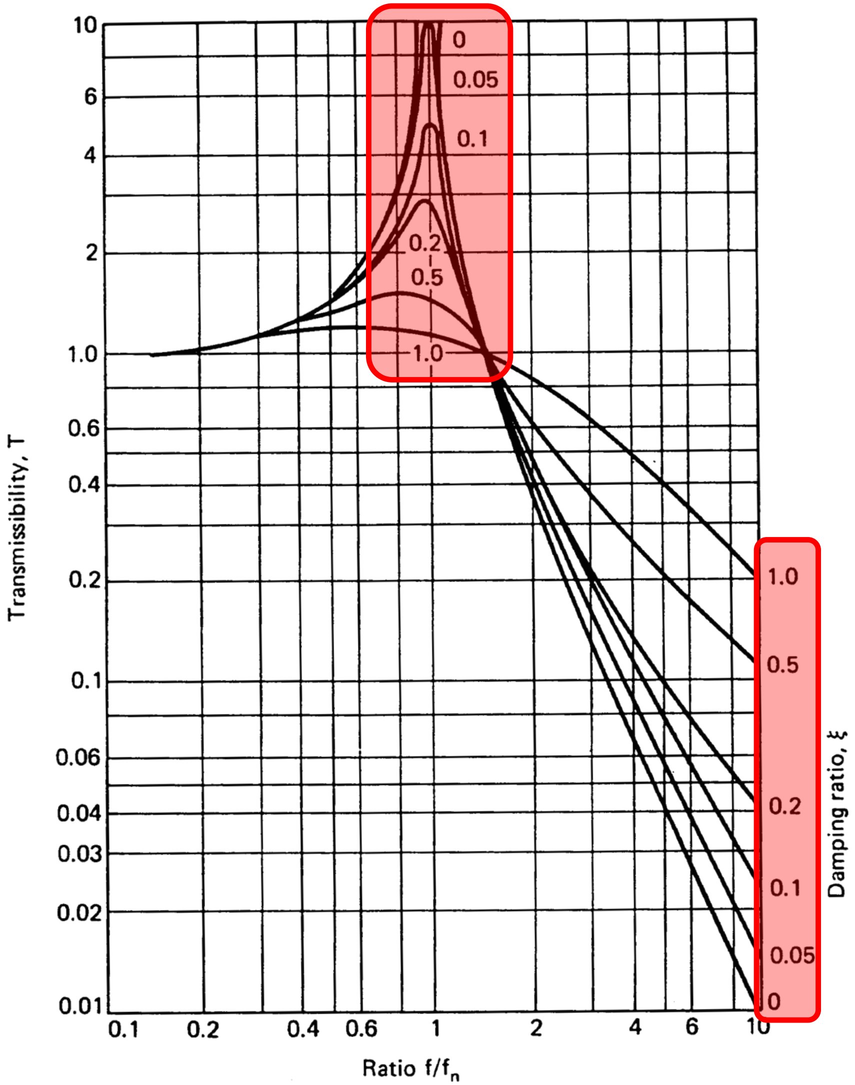
Damping

- Reduction in amplitude over each consecutive oscillation

Coil Spring: Damping = 0



Elastomeric: Damping = 0.01 (1%) - 0.1 (10%)



- Damping reduces the effects of resonance

Stiffness

- **Static Stiffness**
- A material's rate of deflection under applied load
- How 'squashy' it is

- **Elasticity**
- Measure of a material's ability to resist a compressive force
- More specifically a materials ability to return back to it's
- Primary mode of failure
- You can have Stiffness without Elasticity
- Elasticity is where vibration isolation comes from

- **Dynamic Stiffness**
- Stiffness under a static load usually isn't the same as stiffness under a dynamic load
- This is known as the:

  "Dynamic to Static ratio"

- DSR = 1 for coil springs
- = up to 2 for rubber
- = 3 – 4 + for recycled rubber

Vibration Control

- Not all about Isolation
- Avoid Resonance at all costs!
- Lowest possible Stiffness isn't always the best
- Highest possible Damping isn't always the best

- Load Bearing Capacity vs Stiffness

  Too Hard – No Isolation

  Too Soft – Will crush to nothing

- Stiffness vs Deflection

  Lightweight floors with low stiffness isolators are bouncy!

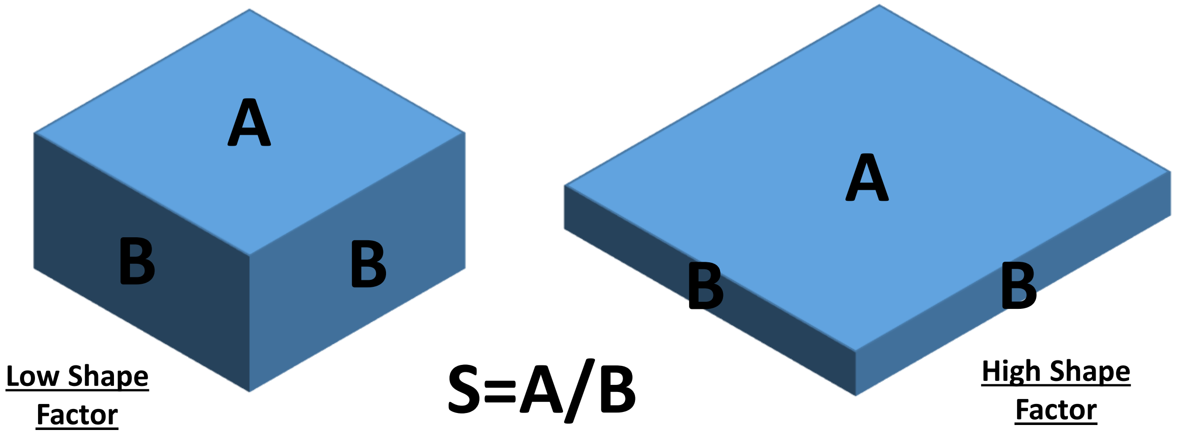
- High Damping vs Low Damping

  Damping $\propto$ Dynamic Stiffness

- Direction of the Load

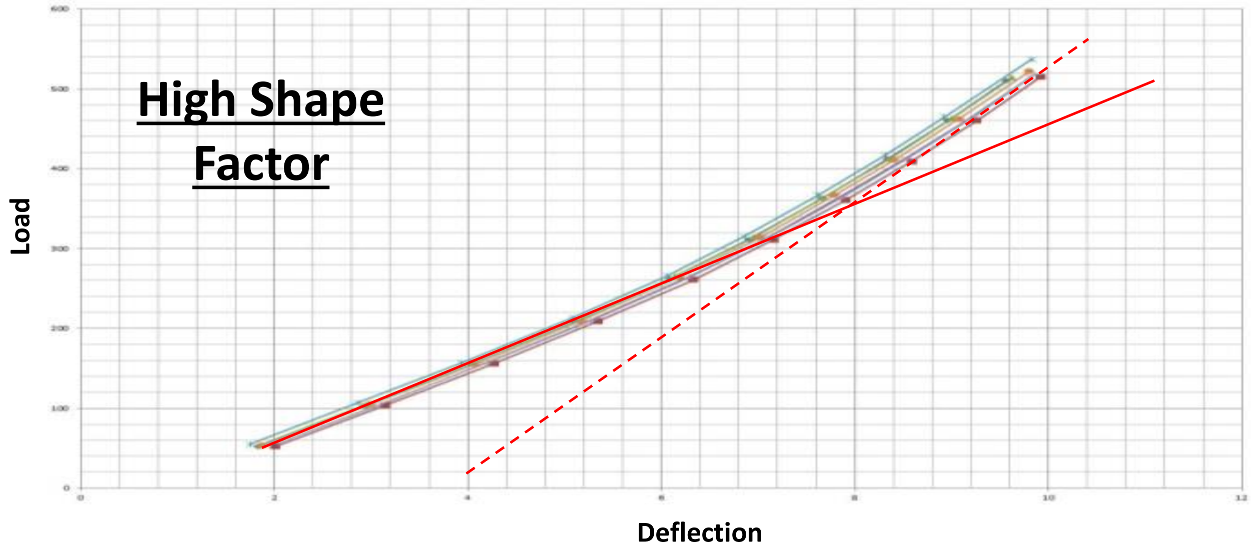
Shape Factor

- The ratio of the loaded surface relative to the area available to bulge:



S=A/B

- Rubber deforms, it does not compress
- Shape factor alters dynamic stiffness

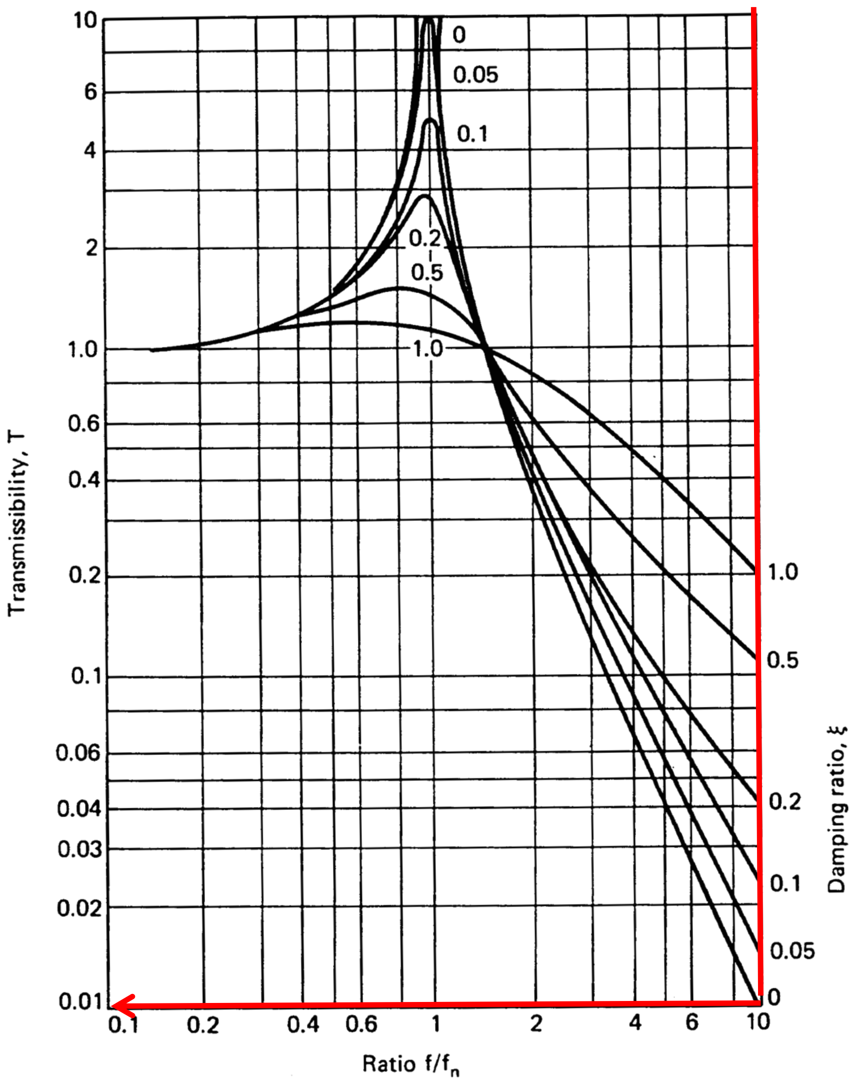


Worked Examples

Worked Example 1a

- Disturbing Frequency [f_e] = 40.0Hz
- Coil Spring

Natural Frequency [f_n] =	3.5Hz
Damping =	0%
Ratio f_e / f_n =	40 / 3.5 = 11.4
Transmissibility =	0.01 (1%)
Isolation =	**99.2%**
dB Reduction =	**42.3dB**



Worked Example 1a

Worked Example 1b

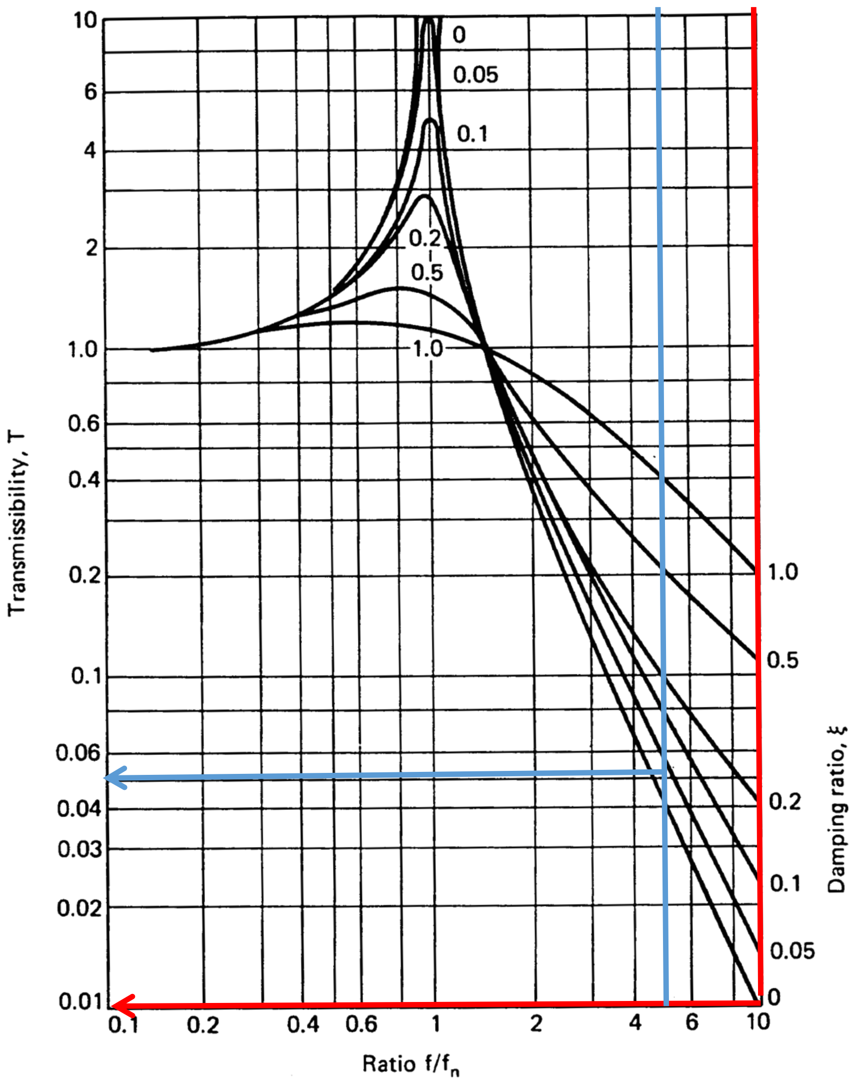
- Disturbing Frequency [f_e] = 40.0Hz

- Coil Spring

Natural Frequency [f_n] =	3.5Hz
Damping =	0%
Ratio f_e / f_n =	40 / 3.5 = 11.4
Transmissibility =	0.01 (1%)
Isolation =	**99.2%**
dB Reduction =	**42.3dB**

- Elastomeric Bearing

Natural Frequency [f_n] =	8.0Hz
Damping =	2-3% = 0.03
Ratio f_e / f_n =	40 / 8 = 5
Transmissibility =	0.05 (5%)
Isolation =	**95.0%**
dB Reduction =	**26.0dB**

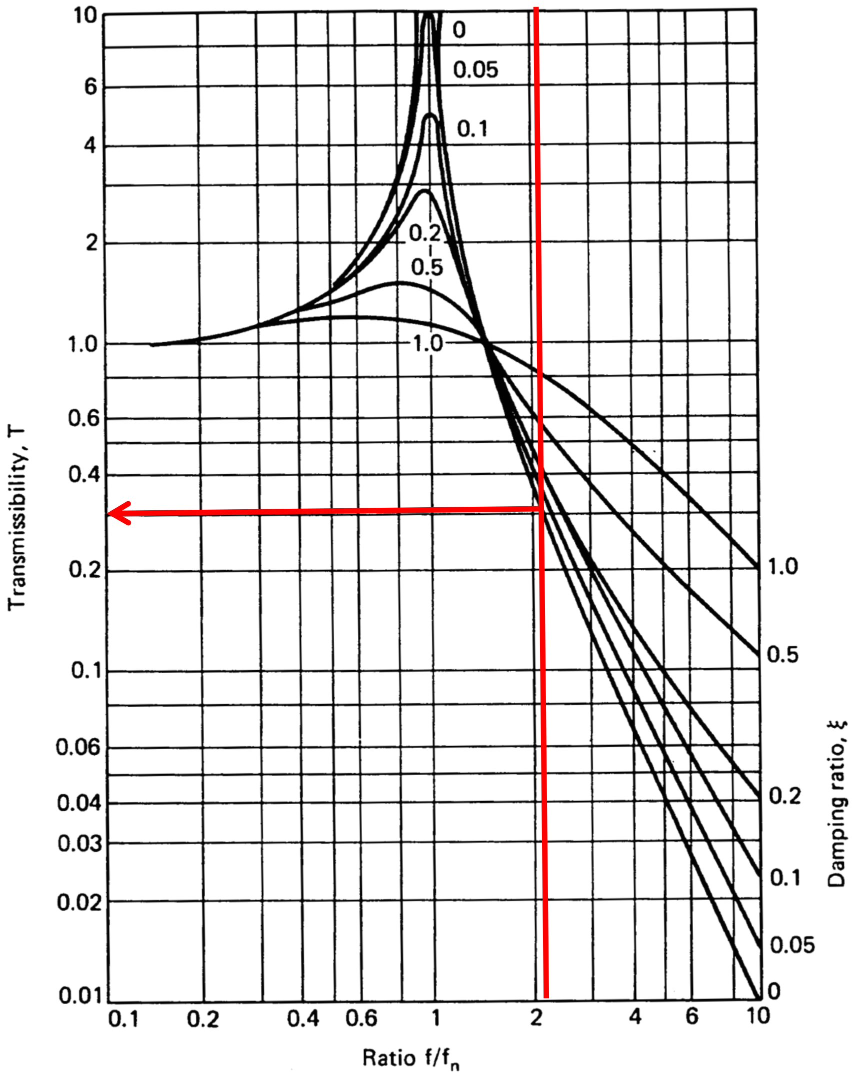


Worked Example 1b

Worked Example 2a

- Disturbing Frequency [f_e] = 12.5Hz
- Coil Spring

Natural Frequency [f_n] =	6.0Hz
Damping =	0%
Ratio f_e / f_n =	12.5 / 6.0 = 2.1
Transmissibility =	0.3 (30%)
Isolation =	**70.0%**
dB Reduction =	**10.5dB**



Worked Example 2a

Worked Example 2b

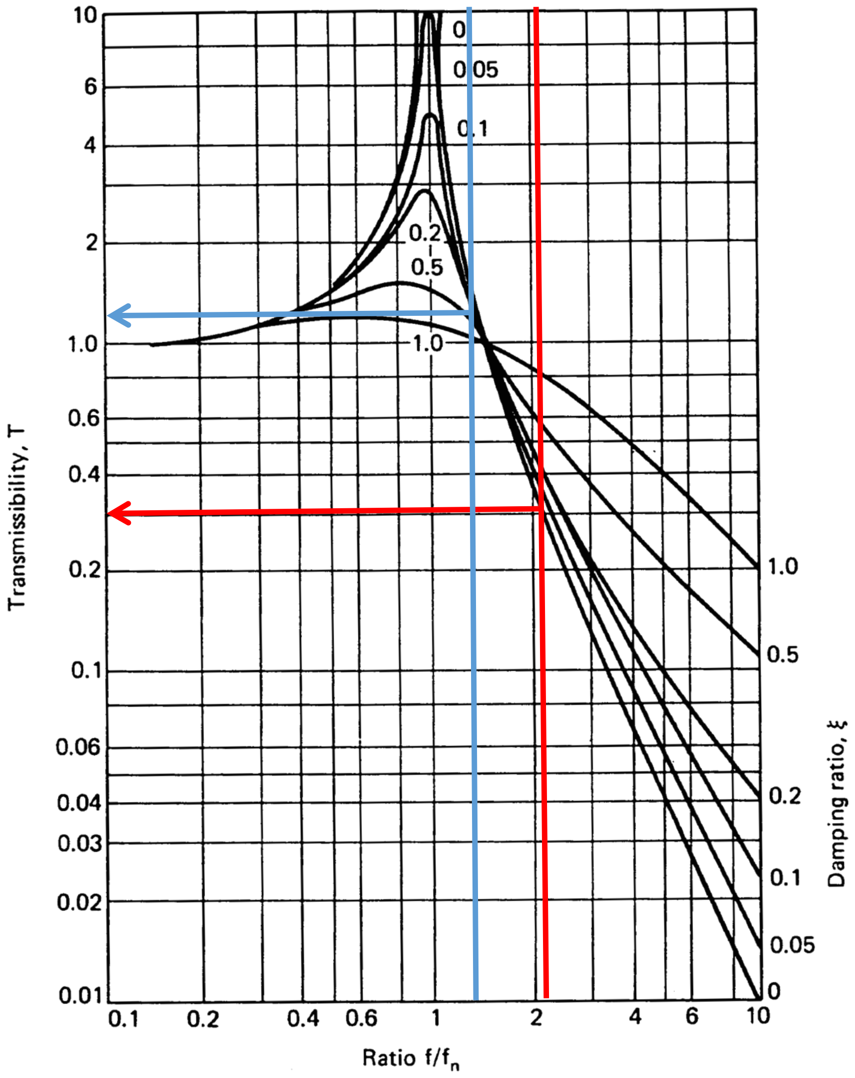
- Disturbing Frequency [f_e] = 12.5Hz

- Coil Spring

Natural Frequency [f_n] =	6.0Hz
Damping =	0%
Ratio f_e / f_n =	12.5 / 6.0 = 2.1
Transmissibility =	0.3 (30%)
Isolation =	**70.0%**
dB Reduction =	**<u>10.5dB</u>**

- Elastomeric Bearing

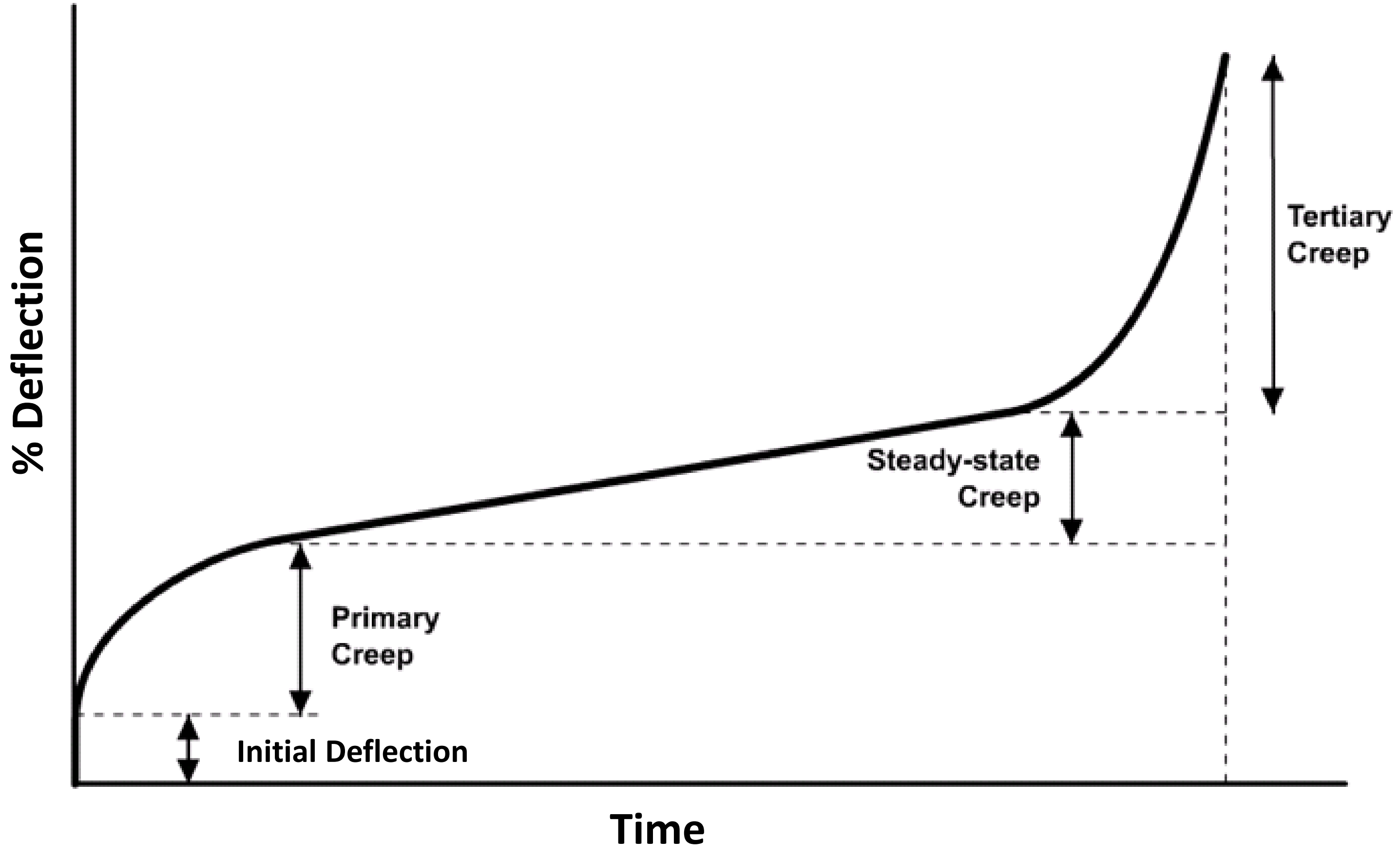
Natural Frequency [f_n] =	9.0Hz
Damping =	2-3% = 0.03
Ratio f_e / f_n =	12.5 / 9.0 = 1.4
Transmissibility =	1.08 (-8%)
Isolation =	**-7.6%**
dB Reduction =	**<u>-0.64dB</u>**



Worked Example 2b

Creep

- The tendency for a material to loose strength and/or relax over time



- Creep is usually measured in Logrithmic Decriments (e.g. 10s, 100s, 1000s, 10,000s)
- So with 10mm initial deflection, 2% Creep: There would be 2% of 10mm = 0.2mm <u>additional</u> deflection each Log Dec of time
- 9 Log Decs = 35.2 Years
- Therefore 2% creep = 10 x 1.02^9 = + 1.7mm
- 9% creep = **+100%** of initial deflection
- Every mm lost to creep is a loss in elasticity that will never be recovered

Recycled Elastomers

- Lower cost as they are made from waste
- Typically rubber particulate with polyurethane binder
- Only suitable for very low strain and low-dynamic applications
- Application is very grade-specific because you must ensure that the rubber is doing the work, not the adhesive
- Dynamic to Static Ratio is very high because the rubber has been vulcanised (at least) twice
- Very good at impact absorption, but not good when amplitude is very low

Recycled vs Non-Recycled

- These slides are not about bashing recycled elastomers
- It is important to know when they are and aren’t ok to use

Isolator Type	Load Bearing Capacity	Dynamic Stiffness	Damping	Creep
Recycled Elastomer	Very Low (<1.5 N/mm^2)	Typically not below 17Hz	Generally Good	10%+
Non-Recycled Elastomer	Wide Range (0.1 – 10 N/mm^2)	As low as 6Hz	Compound Specific	2 – 3%

- Recycled Elastomers are not suitable for exposure to: Lubricating Oils, Diesel/Gasoline, UV Light, Trapped Moisture

Why is this Important?

- The U.A.E. is a very cost-driven market (despite it's aspirations)
- Specifications are changed very often as a result
- This can be in pursuit of value engineering
- But most of the time, it is due to lack of understanding
- **Be better Acousticians!** – Don't let manufacturers use the "it has worked before" argument
  (That doesn't transfer any liability from you onto them)