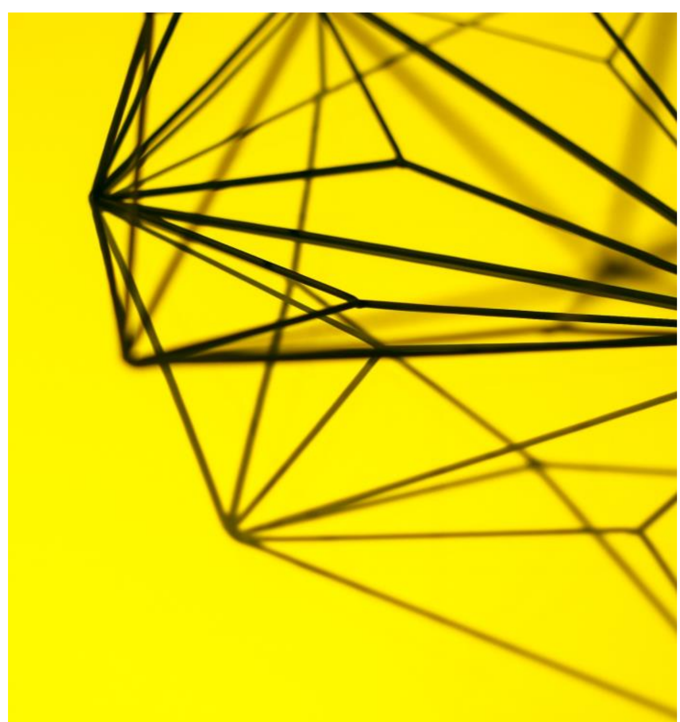
DESIGN MODIFICATIONS

Arnaud Deraemaeker
Arnaud.Deraemaeker@ulb.ac.be

1

PROBLEM STATEMENT



2

Typical frequencies of footbridges

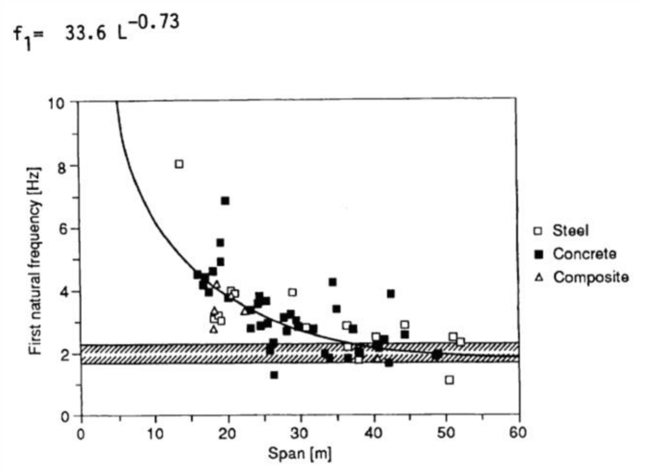


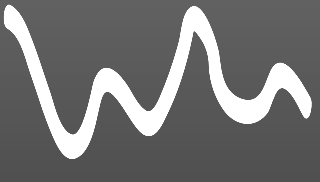
Figure 1.1: Footbridge fundamental frequency as a function of span

[Vibration problems in structures, H. Bachman, 1995]

3

3

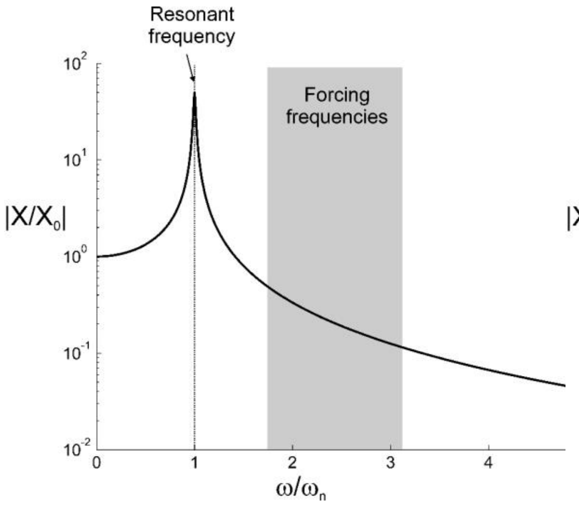
HIGH AND LOW TUNING



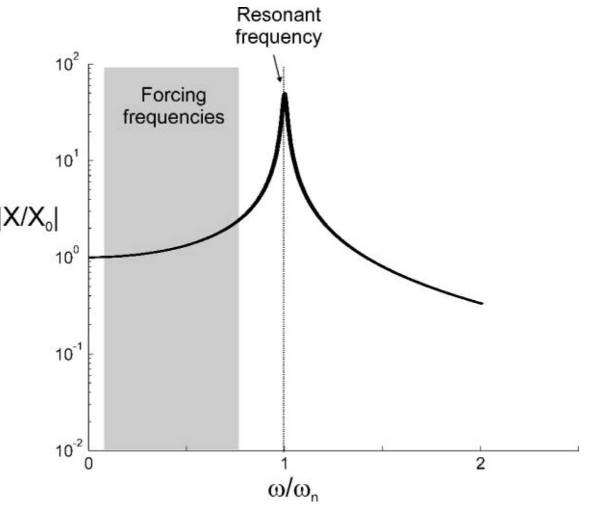
4

High tuning vs low tuning

Low tuning



High tuning



5

5

Footbridges : influence of stiffness

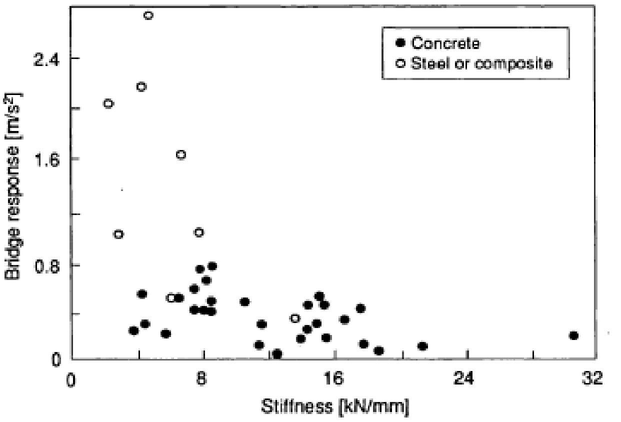


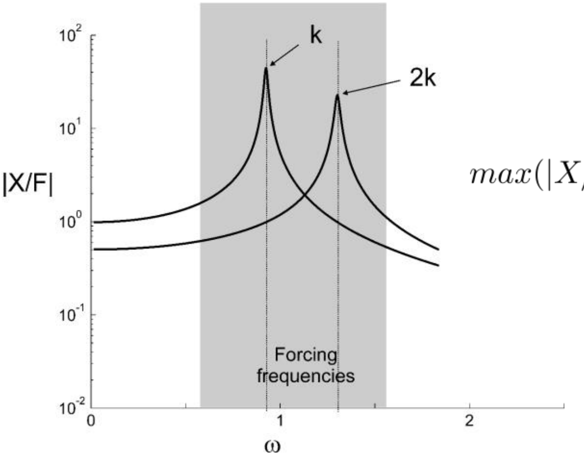
Figure 1.3: Bridge response to a pedestrian walking at f_1 in relation to stiffness

[Vibration problems in structures, H. Bachman, 1995]

6

6

Stiffening

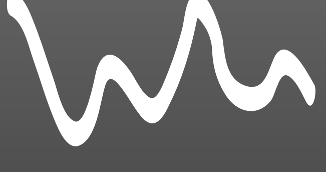


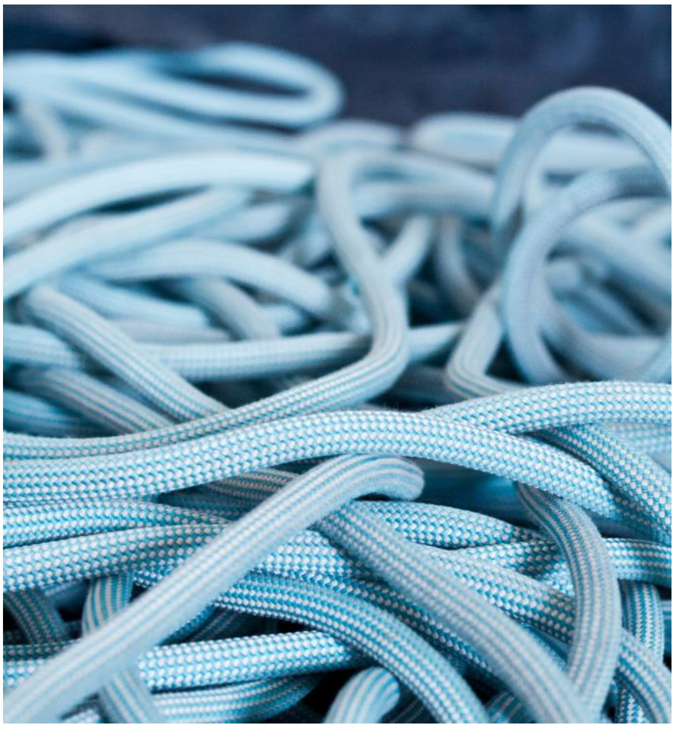
$$max(|X/F|) = \frac{1}{2\xi}\frac{F}{k}$$

→ Stiffening leads to lower vibration for the same value of damping 7

7

ADDING DAMPING





8

Footbridges : influence of damping

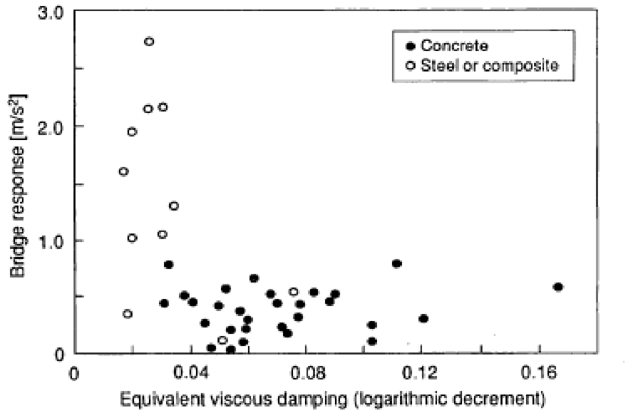
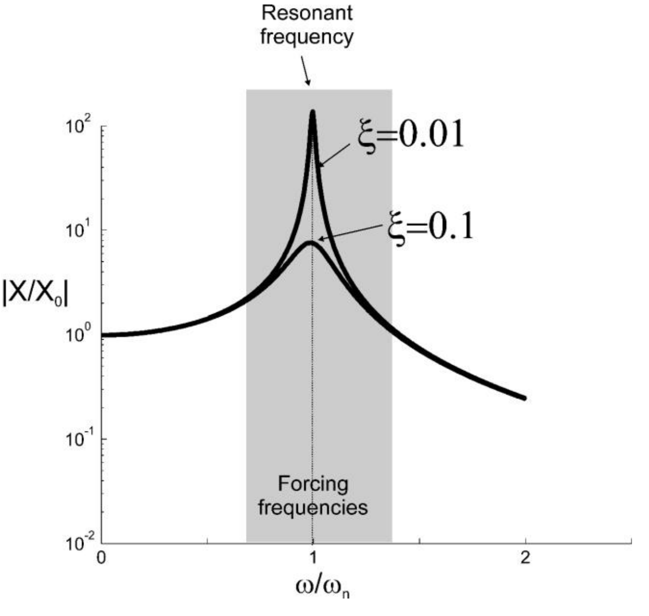


Figure 1.2: Response of footbridges to a pedestrian walking at f_1 for different values of damping

[Vibration problems in structures, H. Bachman, 1995] 9

9

Adding damping

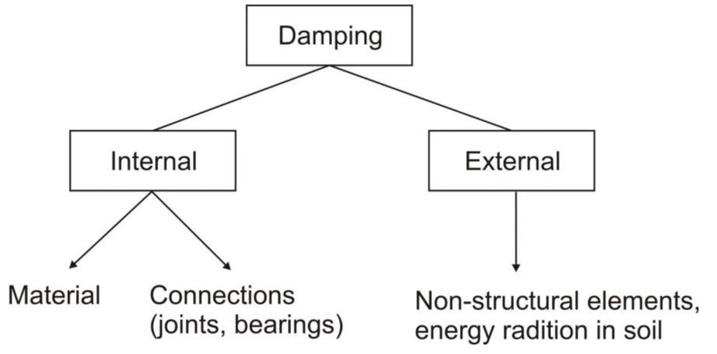


10

10

Types and origin of damping

Damping = dissipation of energy



→ Local damping models

[Vibration problems in structures, H. Bachman, 1995]

11

11

Material damping

Viscous damping

$$C_i = \alpha_i K_i$$

In each material (time domain computations)

Loss factor – Hysteretic damping

$$E(1 + i\eta(\omega))$$

Loss factor can be different for each material and frequency dependent (frequency domain computations)

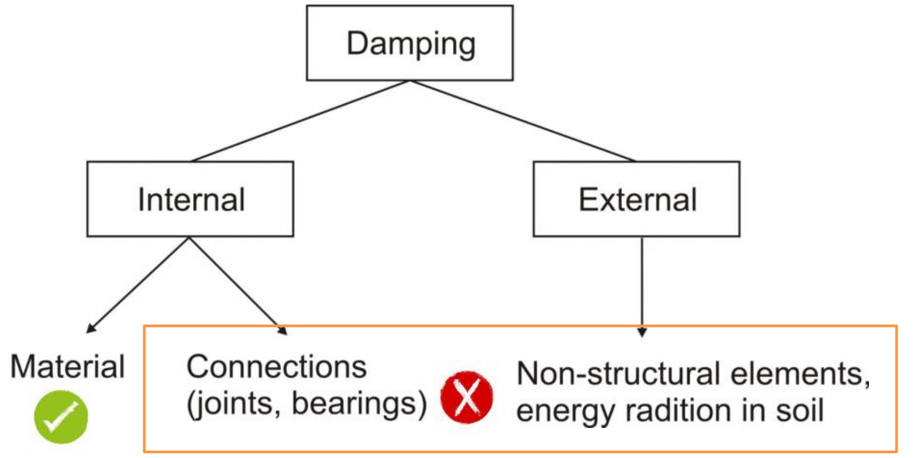
→ Those damping coefficients can be identified experimentally on small material samples

Material	ξ
Reinforced concrete	0.004-0.012
Composite	0.002-0.003
Steel	0.001-0.002

12

12

Contributions to damping



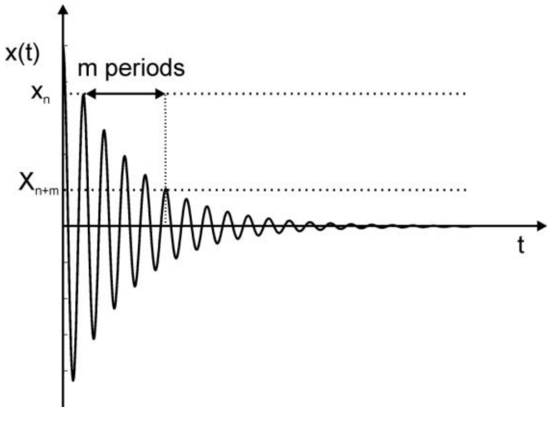
→ Damping coefficients are usually derived from practice or measured if the structure is built

13

13

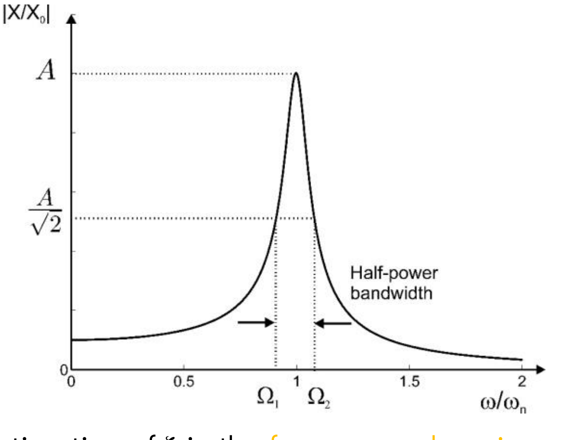
Estimation of damping

Logarithmic decrement method



Estimation of ξ in the time domain

Half-power bandwidth

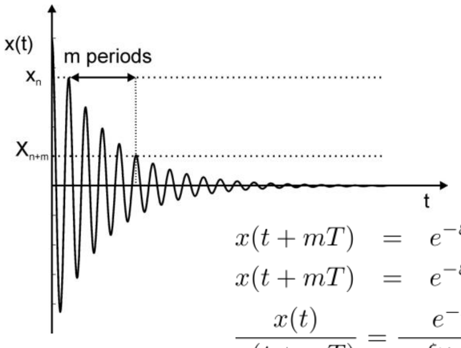


Estimation of ξ in the frequency domain

14

14

Logarithmic decrement method



Free response

$$x(t) = e^{-\xi\omega_n t}\left(Acos(\omega_d t) + Bsin(\omega_d t)\right)$$

$$x(t+mT) = e^{-\xi\omega_n (t+mT)}\left(Acos(\omega_d (t+mT)) + Bsin(\omega_d (t+mT))\right)$$

$$x(t+mT) = e^{-\xi\omega_n (t+mT)}\left(Acos(\omega_d t) + Bsin(\omega_d t)\right)$$

$$\frac{x(t)}{x(t+mT)} = \frac{e^{-\xi\omega_n t}}{e^{-\xi\omega_n (t+mT)}} = e^{\xi\omega_n (mT)}$$

$$\Lambda = ln\left(\frac{x(t)}{x(t+mT)}\right) = \xi\omega_n(mT) = \xi m \frac{2\pi}{\omega_d}\omega_n = 2m\pi\xi\frac{1}{\sqrt{1-\xi^2}}$$

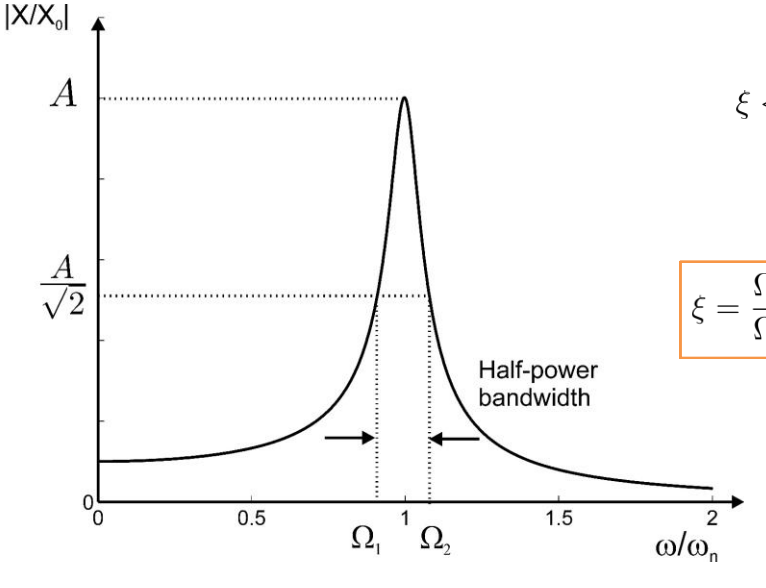
$$\xi^2 << 1$$

$$\xi = \frac{1}{2\pi m}\Lambda$$

15

15

Half-power bandwidth



$$\xi < 0.1$$

$$\xi = \frac{\Omega_2 - \Omega_1}{\Omega_2 + \Omega_1}$$

16

16