

IDENTIFICATION OF DAMPING IN SOIL BY MEANS OF MORLET WAVELETS

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1. Introduction

Most of the common methods for experimental determination of the damping parameters use the proportional damping assumption. The equations of motion for free vibration of a viscously damped linear discrete system with N degrees of freedom can be written as

$$\mathbf{M}\mathbf{y}(t) + \mathbf{C}\mathbf{y}(t) + \mathbf{K}\mathbf{y}(t) = \mathbf{0}, \quad (1)$$

where \mathbf{M} , \mathbf{C} and \mathbf{K} are $N \times N$ mass, damping and stiffness matrices, respectively, and $\mathbf{y}(t)$ is the $N \times 1$ vector of the generalized co-ordinates.

A typical procedure can be described to determination of damping by used modal method [1]:

1. Measure a set of transfer functions $H_{ij}(\omega)$ at a set of grid points on the structure.
2. Obtain the natural frequencies ω_k by a pole-fitting method.
3. Evaluate the modal half-power bandwidth $\Delta\omega_k$ from the frequency response functions, then the Q -factor $Q_k = \omega_k / \Delta\omega_k$ and the modal damping factor $\xi_k = 1/2Q_k$.
4. Determine the modal amplitude factors a_k to obtain the mode shapes, \mathbf{z}_k .
5. Finally, reconstruct some transfer functions to verify the accuracy of the evaluated parameters.

Such a procedure does not provide reliable information about the nature or spatial distribution of the damping, though the reconstructed transfer functions may match the measured ones well.

Methods to attempt to obtain the viscous damping matrix from the experimental measurements can be divided into two basic categories: (a) damping identification from modal testing and analysis [2], and (b) direct damping identification from the forced response measurements [3]. All these methods are based on the assumption that the damping mechanism of the structure is viscous, and their efficiency when the damping mechanism is not viscous is largely unexplored. In a soil damping depends on a strain values, and is proportional for a small strain and non-proportional for a large strain (see Fig. 1).

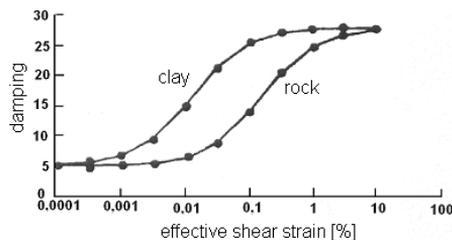


Fig. 1. Damping in a soil

2. Damping calculation by wavelet transformation

As a consequence of the windowing applied by the Gaussian function in the Morlet wavelet, the bandwidth of the resulting wavelet instantaneous spectra are larger than their Fourier equivalent. This gives the appearance of a larger value of effective damping in the signal, the extent of which depends on the scale analyzed. Consider the Morlet wavelet expression the half-power bandwidth

can be used to provide a simple measure of the bandwidth of wavelet spectra [4,5]. Assuming symmetry of the spectral peak, the HPBW is then defined as the difference between these two frequencies: $B_r = f_2 - f_1$, with the frequency corresponding to the spectral peak taken as the natural frequency of the system. Due to the multi-resolution nature of wavelets, wavelet spectra broaden toward the higher frequencies, but for a narrowbanded spectrum, the assumption of symmetry can be retained. Therefore, the scale at which this half-power bandwidth is evaluated should be the scale defining the ridge of the transform, at which the signal energy is focused. Damping coefficient in HPBW method is defined as:

$$\xi = \frac{B_r}{f_1 + f_2} \cdot 100. \quad (2)$$

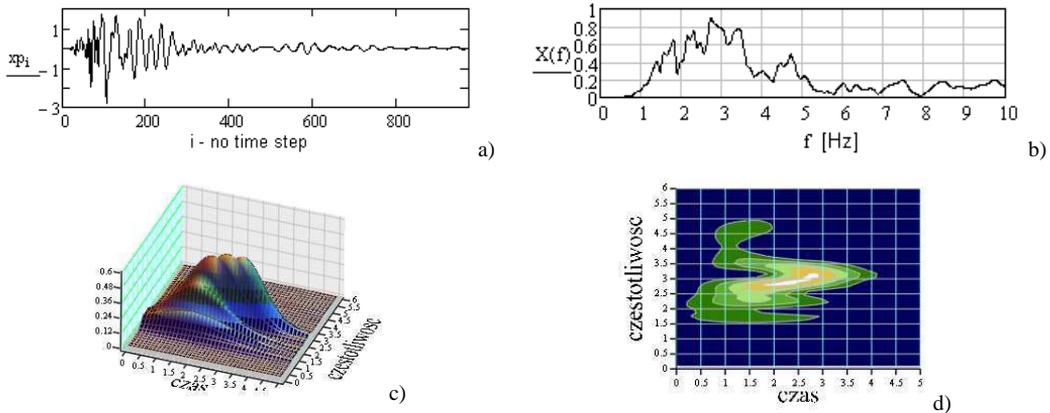


Fig. 2. Damping calculation by HPBW method: a) acceleration in time in horizontal direction, b) Fourier transformation, c), d) wavelet map with Morlet wavelets function,

3. Example of damping calculation by wavelet transformation

We consider a problem of damping calculation base on the measurement date of the Szombierki mine crump. Fig. 2a shows the measurement data in time. Damping according to eq. (2) are shown in table 1.

Table 1.

f [Hz]	1.7	2.2	2.7	3.0	3.2
ξ [%]	27.7	9.8	11.2	9.1	8.6

4. References

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