Experimental evaluation of wavelet based damage monitoring of a reinforced concrete frame

Marek Nalepka[1], **Zbigniew Zembaty**[2], **Seweryn Kokot**[3]

[1,2,3] *Faculty of Civil Engineering, Opole University of Technology*
Katowicka 48 45-061 Opole, Poland
e-mail: m.nalepka@po.opole.pl [1], z.zembaty@po.opole.pl [2], s.kokot@po.opole.pl [3]

Abstract

Possibilities for damage diagnosis by means of continuous wavelet transforms are investigated on an example of seismic response of a reinforced concrete (r/c) frame subjected to shaking table tests. The linear and nonlinear responses are compared using various wavelets. The results demonstrate characteristic development of wavelet ridge and peak patterns following accumulation of damage in the r/c frame which is a good prognostic for wavelet application in on-line monitoring of r/c structures.

Keywords: vibrations, Structural Health Monitoring, reinforced concrete, continuous wavelet transform

1. Introduction

Wavelet transform plays a significant role in vibration-based structural damage detection (see e.g. [3]). Respective damage detection can for example be obtained through a spatially applied wavelet [1]. However the wavelet transform can also be applied in time domain. In this case the specific differences of the linear structural response compared to non-linear response with energy dissipation in damaged state are investigated with the application of wavelet transform. Such an approach was already investigated [2]. Its experimental validation is a critical issue now.

The lecture proposed for the 3rd PCM-CMM Congress will present early results of the application of Morlet wavelet to evaluate data acquired during a shaking table experiment devoted to modal analysis of an R/C frame in various damage states [4].

2. Description of the experiment

The analysed reinforced concrete frame was one of two frames taken in an experiment described in detail in a paper by Zembaty et. al [4]. The frame was subjected to artificially generated, two-component seismic signals on a shaking table (see Fig. 1). The excitation intensity was changed during the tests, stage by stage using a multiplier of the original signal. This resulted in linear excitations at the beginning of the tests until strong damaging effects. Each phase of strong ground motion was interlaced with a series of diagnostic small excitations (sweep sine, random tests, time history excitations) aiming at retrieving evolution of the modal parameters of the damaged frame described in detail in Ref. [4]. From this experiment two acceleration records of sensor A22 (Fig. 1) were chosen for the wavelet analysis. From the early stage, linear response of intact frame with maximum value of 35,6 cm/s^2 for which the dynamic parameters of the frame equalled T_1=0,21 s (translational mode along x axis), T_2=0,17 s (along y axis) and T_3=0,10 s (torsion). The second record represents nonlinear dynamic response with 319,0 cm/s^2. Respective, "linearized" natural frequencies of the frame (taken from post-damage diagnostic tests) equalled: T_1=0,35 s, T_2=0,28 s and T_3=0,13 s.

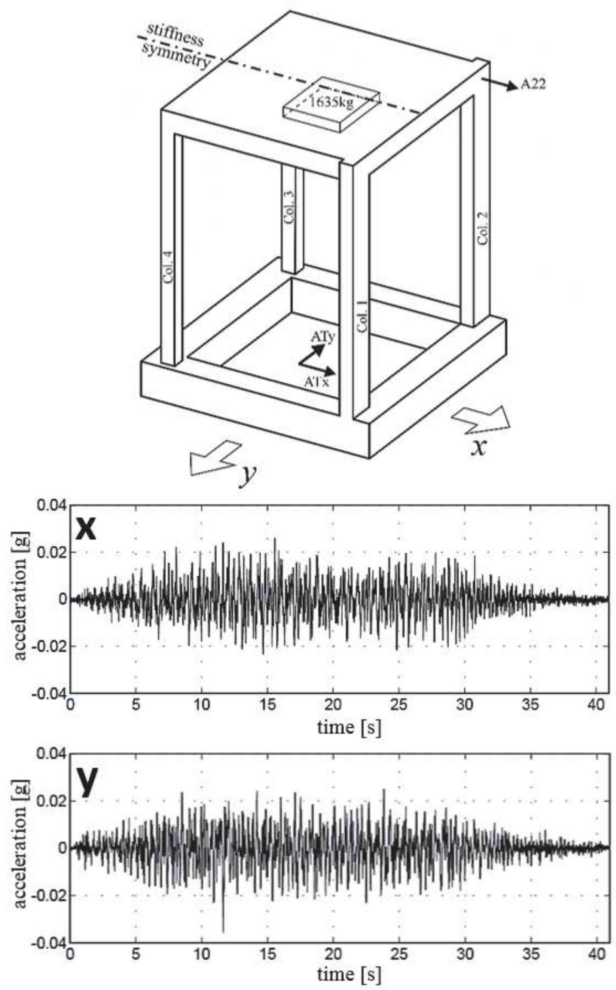

Figure 1: Analysed frame with location of accelerometer A22 and seismic records of accelerations (along x and y axis)

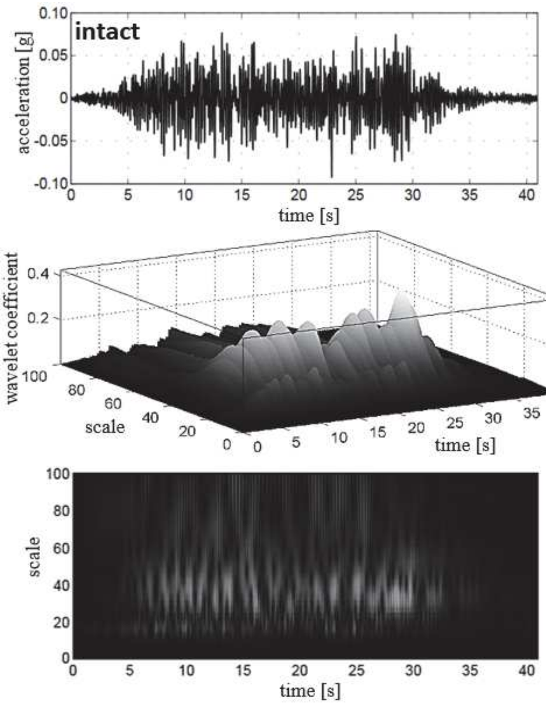

Figure 2: Wavelet coefficients of the acceleration response of not damaged structure

3. Application of Continuous Wavelet Transform to observe damage evolution

The continuous wavelet transform (CWT) of a function, represents the function or the time history *f(t)* as a sum of dilated (by a scale parameter *a*), the scale in this case related to the frequency of wavelet, and time-shifted (by a shift parameter *b*) wavelets. Because wavelets are localized waves that span a finite time duration, CWT can represent time-varying characteristic of *f(t)*. The CWT is defined as follows:

$$Wf(a,b)=\int_{-\infty}^{\infty} f(t)\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right)dt \qquad (1)$$

where $\psi(t)$ is the so-called mother wavelet chosen depending on the wavelet application. The mother wavelet is extended by scale parameters and translate over the *f(t)* by shift parameter *b*, which creates basic functions called daughter wavelets.

In Figures 2 and 3 selected results of the application a Morlet wavelet as the mother wavelet are presented. The specific puls like shape and a good time-frequency resolution of the Morlet wavelet makes its application in this case particularly plausible. Scale of daughter wavelet of Morlet wavelet correspond pseudofrequency to the natural frequency of structure. Comparing the wavelet map of the linear response (Fig. 2) with the non-linear one (Fig. 3) we notice that as the damage extent increase, the peaks of ridges of wavelet coefficients shifts both in time and scale. Changes in scale represent loses of high-frequency components due to loss of stiffness. As the intensity of damage increases the wavelet coefficients spread in time.

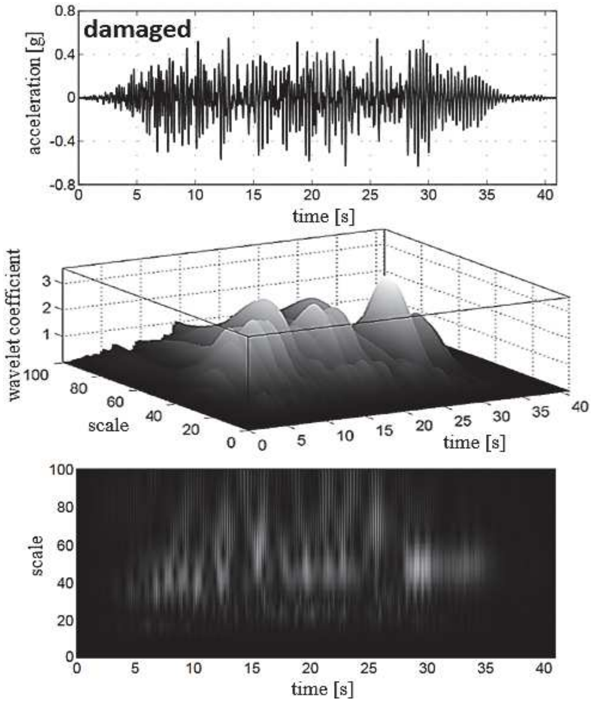

Figure 3: Wavelet coefficients of the acceleration response of damaged structure

4. Conclusion

Wavelet analysis of all the response records of the r/c analyzed frame reveals clear, characteristic changes in the development of the wavelet ridges and peak patterns from the moment the structure starts to accumulate damage. This validates the **qualitative** positive assumption of applying the wavelet approach in the damage monitoring of r/c structures under strong, damaging dynamic excitations. The aim of the ongoing research is to build and test software capable of raising alarms of the imminent structural damage. At this stage various methods are tested. Detailed results of **the quantitative** comparisons will be reported during the Congress.

References

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