Czech Society for Nondestructive Testing
NDE for Safety / DEFEKTOSKOPIE 2011
November 9 - 11, 2011 - Harmony Club Hotel, Ostrava - Czech Republic

NON-DESTRUCTIVE EVALUATION OF THE CONCRETE STRUCTURE DAMAGE

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Abstract
The present paper deals with an experimental study of the frequency inspection method applicability to the concrete structure integrity damage assessment. Our research has addressed to three groups of specimens which differed from each other in the structure quality, because of different concrete ageing conditions, were subjected to the degradation. Our objective consisted in determining how the freeze-thaw cycle application induced degradation depends on the structure initial quality. The measurement results of the specimens (the best structure quality) which had undergone degradation showed no frequency spectra changes and no predominant frequency shifts. Specimen groups of which quality was inferior due to the lack of water during the ageing process showed a shift of the predominant frequencies toward higher frequencies. However, it was an upward shift which we are interpreting as a symptom of the specimen structure improvement – contrary to our expectations. The structure integrity improvement is in our opinion due to the additional hydration of mixed cement grains in consequence of specimen soaking in water in the course of the freeze-thaw cycles. It was verified that this method is appropriate to concrete structure changes assessment.

Key words: *concrete ageing conditions, structure integrity, micro-cracks, frequency inspection*

1. Introduction

The frequency inspection method is used for non-destructive quality evaluation of building elements and concrete and masonry structures. It is based on the propagation of stress waves, which are generated by a mechanical impulse. A short-duration mechanical impact, produced by tapping a hammer or a small steel ball against the surface of tested object produces low-frequency stress waves (from 1 to 60 kHz) that propagate into the structure and are reflected by flaws and/or external surfaces [1 - 3]. Reflected waves are recorded on the surface by a sensor in the form of a voltage signal. The resulting voltage versus time plot (time-domain realization) is digitized and fed into the memory of a computer, which subsequently carries out the frequency analysis of it. What results are a time realization and the corresponding frequency spectrum display. The predominant frequencies (which are represented by local maxima in the spectrum) may be associated with multiple reflections within the structure, carrying information on the structure integrity and defect localization [4 - 6].

2. Experimental part

The three groups of the specimens of dimensions 4cmx4cmx16cm were prepared from a cement screed and mixed cement III was used. The first specimen group

(denoted V) was kept, in accordance with standard conditions, in water for the entire ripening period (28 days). In this case no water content reduction took place. The second specimen group was kept in air in laboratory environment conditions (denotation L). In consequence of water content reduction after hardening, the specimens shrank and microcracks arose in the specimen structure. The third specimen group (denoted S) was placed for twelve days of the ripening process into a dryer in which the air temperature was 60°C in order to increase the specimen load and get heavier structure deterioration. All three sample groups were placed in laboratory environment conditions for 8 months and then underwent 25 freezing cycles according to the norm CSN 73 1380. One cycle represented freezing the sample for 4.5 hours to -24°C and subsequent warming to 20°C for 2 hours. Three samples from the group V were left in laboratory environment conditions and denoted as reference samples V_r. The goal of the experiment was to evaluate the influence of the sample structure quality (different concrete ageing conditions) on the effect of degradation by freezing cycles.
The frequency inspection method was applied to the tests of concrete specimens before and after degradation. A special hammer provided longitudinal excitation. The mechanical impulse was applied by a special hammer and a piezo-electric sensor was used to pick up the response. The measurements results are represented in the form of the specimen response frequency spectra as shown in Figs 6 through 8.

3. Measurement results

Fig. 1 compares the results of two measurements of reference specimens carried out at different times. They are represented by specimen No V_r 4.

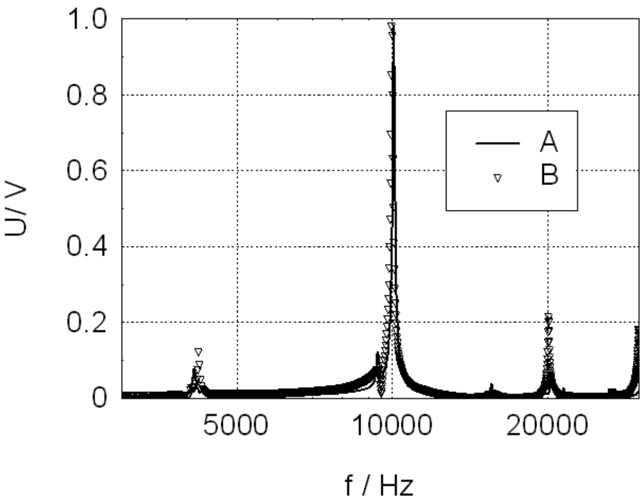

Fig. 1 Response frequency spectrum of intact reference specimen V_r4

Curve A represents the measurement carried out on 12.5.2011, whereas curve B belongs to the measurements of 11.8.2011. It is evident that no shift of the predominant frequency component is taking place in this case.

The next Figure, No. 2, compares the results obtained from V1 before and after the thermal degradation. It represents the results obtained from the group of V specimens. During the ageing period, these specimens were kept – according to standard conditions – in water.

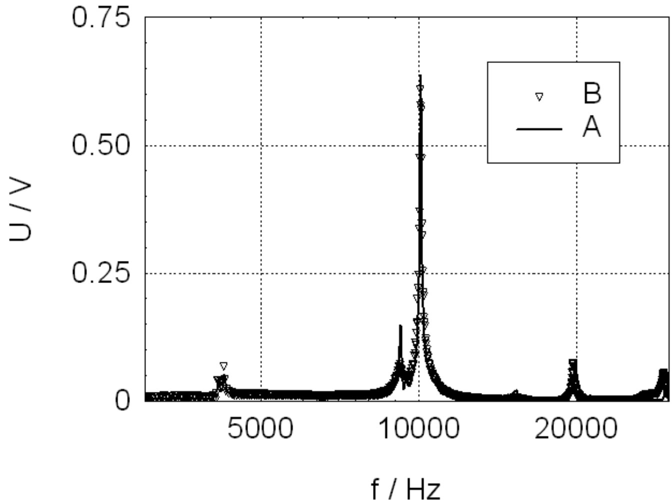

Fig. 2 Response frequency spectrum of V1 specimen, which was kept in water for the entire ripening period, A - before degradation, B – after degradation

In this diagram, curve A shows the measurement results obtained prior to the specimen degradation (measurement date, 9.5.2011), whereas curve B belongs to the post-degradation measurements (measurement date 11.8.2011). The comparison shows clearly that no predominant frequency shift has taken place in this case, which indicates that the application of 25 freeze-thaw cycles has not resulted in any structure damage.
The next Figure No. 3 represents the L-specimen group. During the ageing period, these specimens were kept in laboratory environment conditions, being exposed to the air but not to the water. The measurement results of this specimen group are represented by those of L1 specimen.
The diagram compares the measurement results obtained before (curve A, the readings having been taken on 13.5.2011) and after the thermal stress (curve B, 11.8.2011). In this case, a slight shift of the predominant frequency components is observed, however, toward higher frequencies, which contradicts our expectations [7]. The respective predominant frequencies prior to and after the thermal degradation were 8 770 Hz and 8 980 Hz, Δf = 210 Hz. The thermal degradation resulted in reducing the second harmonic frequency magnitude. Based on the predominant frequency upward shift, it may be supposed that the specimen structure integrity has improved in consequence of the thermal stress. The thing is that the specimens are soaked in water in the course of the degradation cycles, which has probably caused additional hydration of cement grains [8, 9].

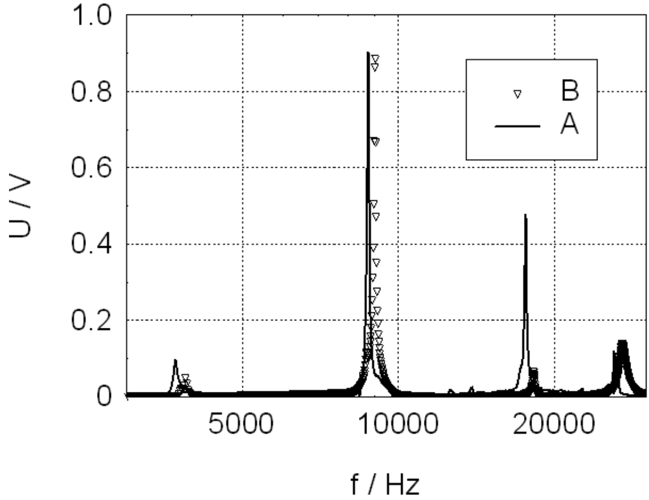

Fig. 3 Response frequency spectrum of L1 *specimen which was stressed by shrinking, A - before degradation, B – after degradation*

The last Figure, No. 4, shows the measurement results obtained from the S-specimen group, whose quality was the worst.

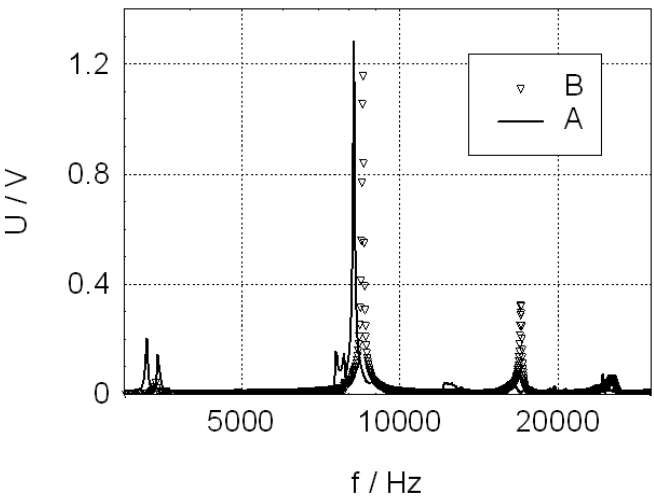

Fig. 4 Response frequency spectrum of S3 specimen which was subjected to stronger stressing, A - before degradation, B – after degradation

The diagram compares the frequency spectra of S3 specimen. Curves A and B correspond to the measurements made before (13.5.2011) and after (11.8.2011) the specimen degradation, respectively. Again, an upward shift of the predominant frequencies is evident: pre-degradation frequency = 8 040 Hz, post-degradation frequency = 8 360 Hz. In this case, the frequency shift is higher, namely, Δf = 320 Hz, which indicates a thermal-stress-induced improvement of the structure integrity, which is considered to be due to an additional hydration of cement grains.

4. CONCLUSION

Our experiments focused on detecting structural changes in concrete specimens (made from mixed cement screed) which were supposed to arise in consequence of the thermal stress being applied in compliance with CSN 73 1380 standard. Three groups of specimens differing from each other in their structure quality, depending on the concrete ageing conditions, were studied. Our experiments aimed at comparing the effect of 25 freeze-thaw cycles on the specimens of three different quality groups.
The 1st group, consisting of the best-quality concrete specimens, showed no frequency spectra changes and no predominant frequency shifts. The same results were also obtained from three specimens of this group which had not been subjected to any thermal stressing, being continuously kept at laboratory conditions.
The second specimen group whose quality was inferior due to the lack of water during the ageing process showed a shift of the predominant frequencies. However, it was an upward shift (toward higher frequencies) which we are interpreting as a symptom of the specimen structure improvement – contrary to our expectations. The structure integrity improvement is in our opinion due to the additional hydration of mixed cement grains in consequence of specimen soaking in water in the course of the freeze-thaw cycles.
Similar results were obtained from the 3rd group specimens (showing the worst quality of the structure). In this case, the frequency shift was still higher.
Our measurements also show that the frequency inspection method is a sensitive structure status indicator, which can also be used to assessing the frost resistance of these building elements.

Acknowledgement
The research described in this paper was supported by the Grant Agency of the Czech Republic under project No. P104/10/1430 and by the research project MSM 0021630519.

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