Application of Frequency Inspection to Comparison Frost Resistance of Fired Roofing Tiles Manufactured Using Old and New Technology

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Abstract

The paper presents some results of our experimental study of the application potential of the frequency inspection method to the non-destructive assessment the frost resistance of fired roofing tiles manufactured using an old technology in 1988 and new technology in 2002. A temperature drop to -70°C was applied to the specimens in order to induce the accelerated degradation.

Introduction

The analysis was applied to two sets of fired roof tiles, of a plain tile type, one which had been fabricated in 1988 using an old technology and second in 2002 using a new technology . A metal hammer of a mass of 169 g, which was hinged in a fixture ensuring a constant release level, h=2 cm [1], was used to hit the tile.

The tile response to the exciting impulse was picked up by means of a piezoelectric sensor of Sedlák S7 type, whose operating frequencies range from 100 Hz to 50 kHz. The sensor was fitted to the tile surface at a point of coordinates x = 17 cm, y = 9 cm, i.e., in the maximum amplitude region [2].

The response voltage was fed into the input of a Yokogawa DL1540CL digital oscilloscope and further processed by means of a special signal-analysis software package.

The accelerated degradation test was carried out by putting the tiles into a cooling box kept at a temperature of -70°C for 10 minutes. The low temperature was achieved by using liquid nitrogen vapours. Subsequently, the tiles were dried in an oven at a temperature of 110°C, to be further exposed to the laboratory temperature for 24 hours for the temperature equalization. A total of four degradation test cycles has been applied.

Experiment results and discussion

Fig. No. 1 shows a recording of No. 5 specimen made using an old technology in 1988, response as picked up at the tile centre prior to the expected low-temperature-induced degradation. Being placed at that point, the sensor picked up the response bending vibration amplitude for the most part. The response impulse duration was 53 milliseconds.

The attenuation ratio was found to equal $\lambda = 58\ s^{-1}$ [3].

Fig. 2 shows the power spectral density (in relative units) versus frequency plot for specimen No. 5. A dominant frequency f_0 = 2591 Hz may be observed.

Fig. 3 shows a response versus time plot as picked up from specimen No.5 after one -70°C degradation test cycles. The response duration is 38 ms, whereas the attenuation constant increased to λ = 128 s^{-1}.

The spectral density vs. frequency recording (Fig. 4) shows that the number of significant frequencies increased in the range from 1,5 kHz to 5 kHz. The dominant frequency appears to have shifted to f_1 = 2801 Hz.

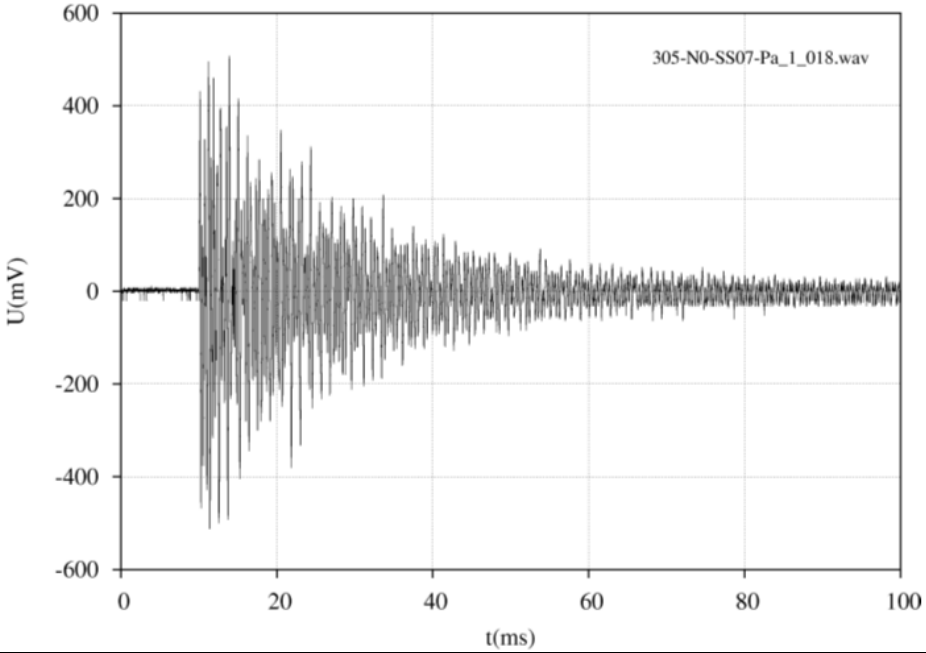

Fig.1 Time-domain response record for a roofing tile No.5, which had been fabricated using an old technology. Measurement was made before degradation.

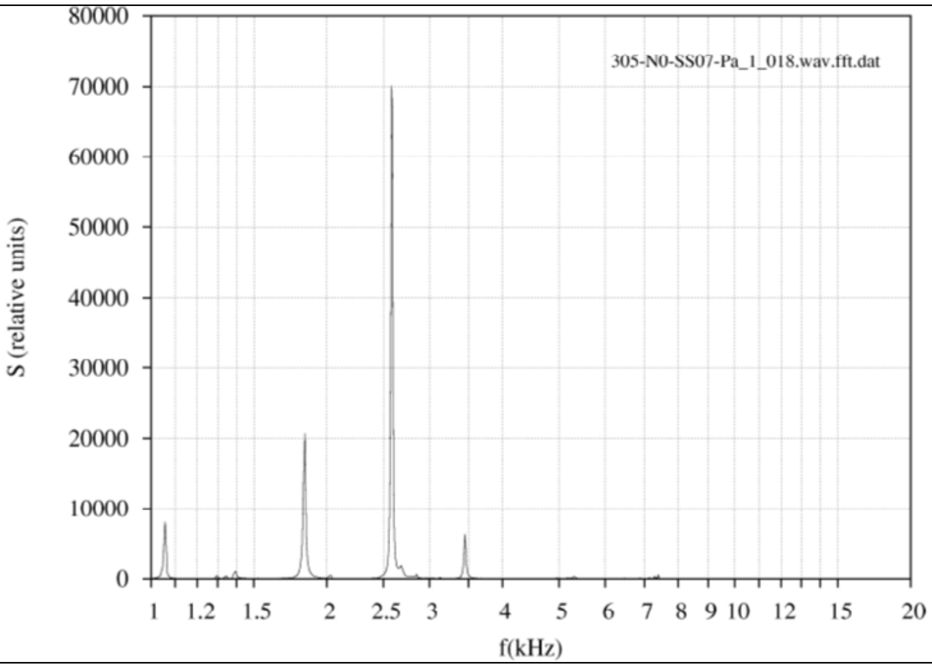

Fig.2 The power spectral density versus frequency plot for specimen No.5, which had been fabricated using an old technology. Measurement was made before degradation.

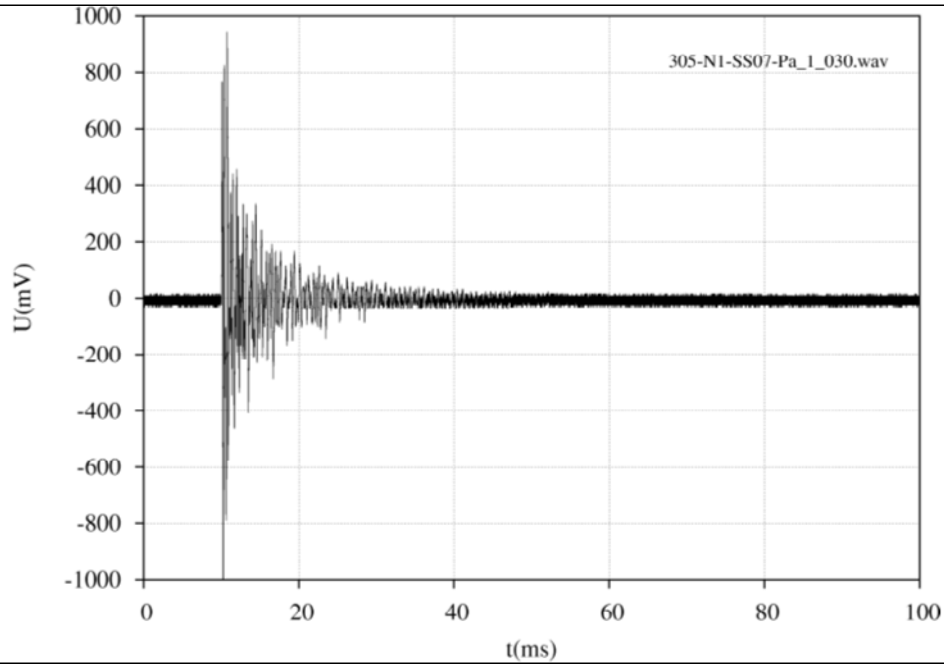

Fig.3 Time-domain response record for a roofing tile No.5 after one -70°C degradation test cycles.

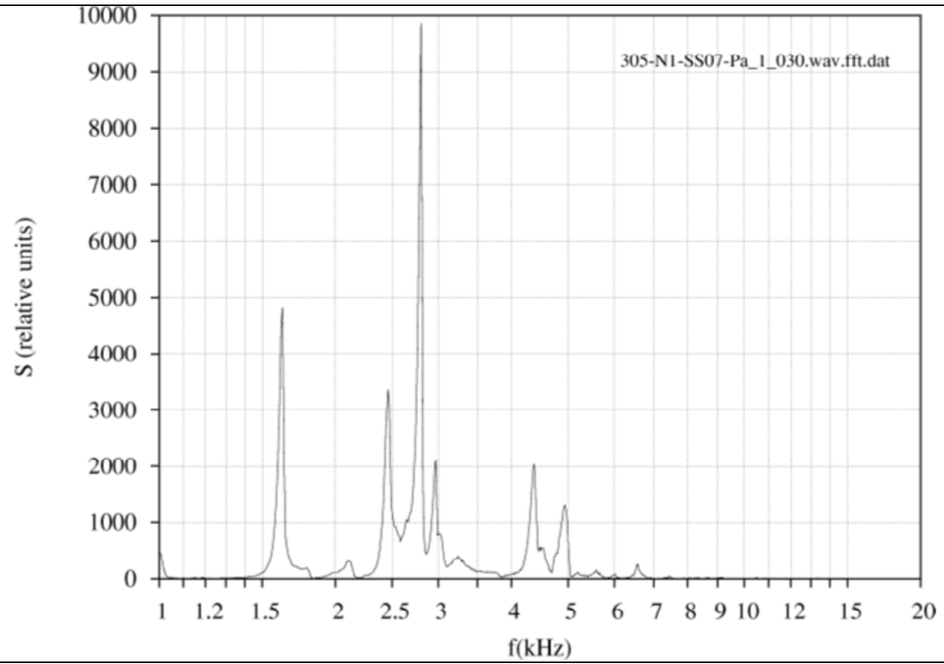

Fig.4 The power spectral density versus frequency plot for specimen No.5 after one -70°C degradation test cycles.

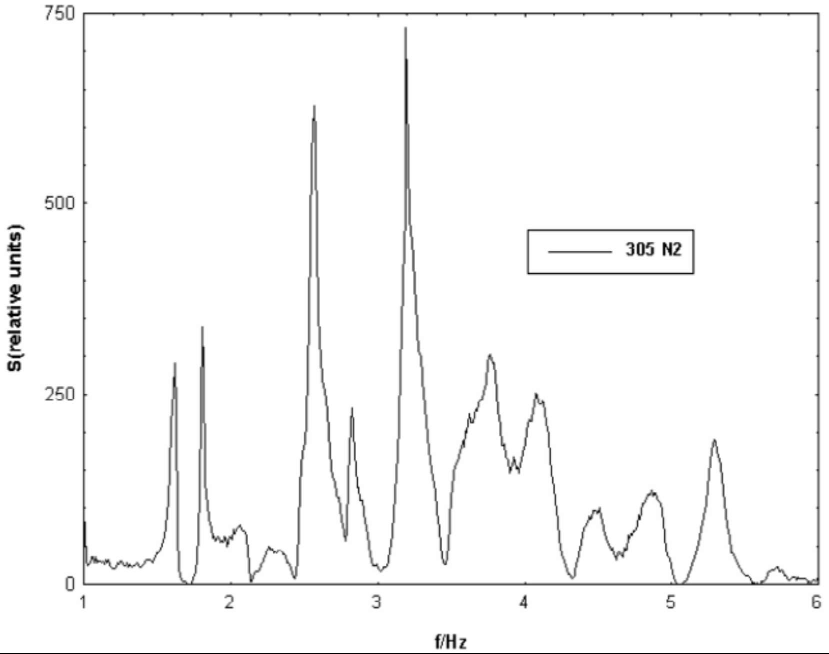

Fig.5 The power spectral density versus frequency plot for specimen No.5 after two -70°C degradation test cycles.

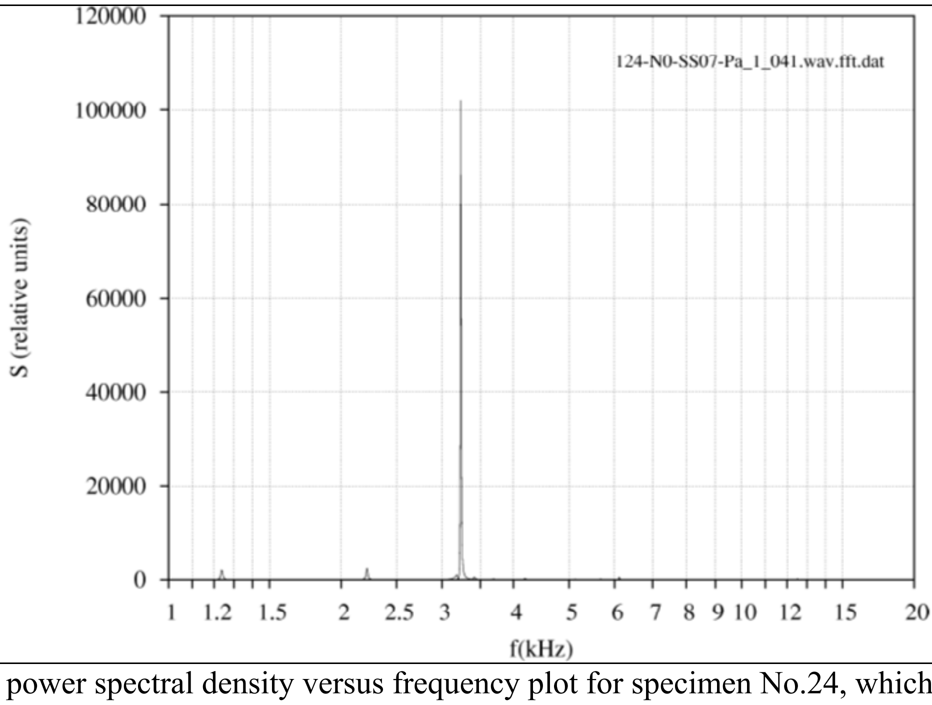

Fig.6 The power spectral density versus frequency plot for specimen No.24, which had been fabricated using a new technology. Measurement was made before degradation.

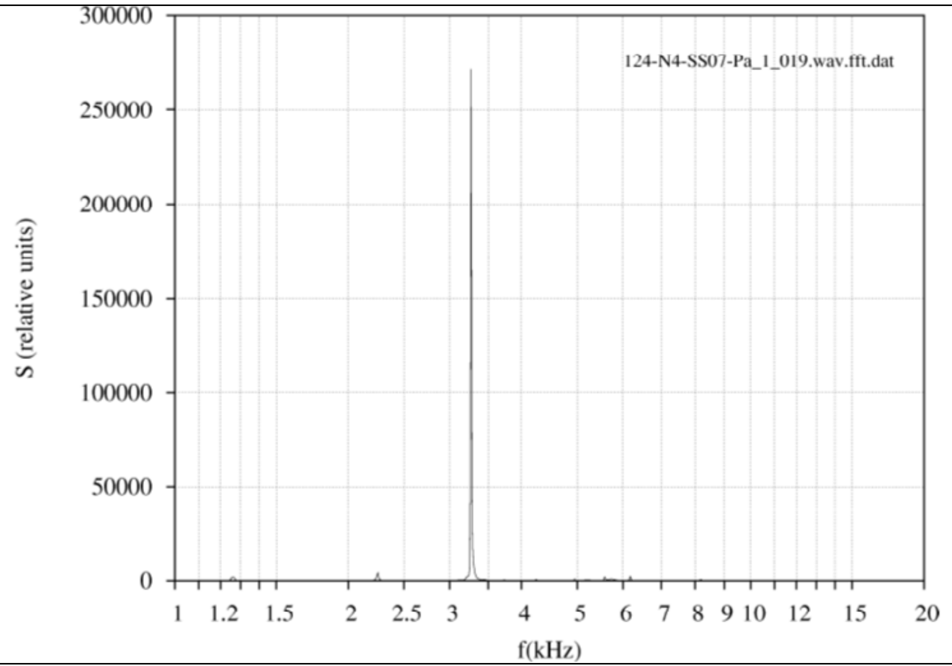

Fig.7 The power spectral density versus frequency plot for specimen No.24 after four -70°C degradation test cycles.

The spectral density vs. frequency recording for specimen No. 5 after two degradation test cycle(Fig. 5) shows that the number of significant frequencies increased in the range from 1,5 kHz to 5 kHz. The dominant frequency appears to have shifted to f_2 = 3198 Hz. The next degradation test cycle resulted in the generation of naked-eye-observable cracks, whose width was 0.5 mm to 1 mm almost throughout the tile length.

Table No. 1 shows the maximum frequencies and the respective attenuation ratios λ, for specimen No. 5 and different degradation test stages.

Table No.1 – specimen No. 5-old technology.

cycle	**λ /s^{-1}**	**f/Hz**
0	58	2591
1	128	2801
2	385	3198

Fig.6 shows the power spectral density (in relative units) versus frequency plot for specimen No. 24, which had been fabricated using a new technology. Measurement was made before degradation. A dominant frequency f_0 = 3234 Hz may be observed.
The spectral density vs. frequency recording for specimen No.24, after four -70°C degradation test cycles. (Fig. 7) shows that a single dominant frequency is left, having been shifted to a higher value, namely, f_4 = 3269 Hz.

Table No. 2 shows the maximum frequencies and the respective attenuation ratios, λ, for specimen No 24 and different degradation test stages.

Table No.2 – specimen No. 24-new technology.

cycle	λ /s^{-1}	f/Hz
0	19	3234
1	22	3239
2	34	3244
3	38	3249
4	53	3269

Conclusion

Two sets of fired roof tiles, of a plain tile type, which had been fabricated in 1988 using an old technology and in 2002 using a new technology, was tested. The tiles were subject to accelerated degradation tests, being cooled down to -70°C.

Remarkable resonance frequency shifts, in the order of magnitude of several hundred Hz, as well as an increase in the number of resonance frequencies, occurred in the course of the degradation tests by the fired roof tiles manufactured using an old technology. In view of the catastrophic breakdowns having occurred during the tests it may be concluded that the roof tile manufacture technology, which was used at that time, proved to be rather outdated, providing no sufficient frost resistance.

The results achieved show that by the fired roof tiles made a new technology, only a low resonance frequency shift, in the order of a few tens of Hz, results from the degradation. It is therefore evident that only insignificant structure change take place in consequence of such a drastic degradation test, which a temperature drop to -70°C undoubtedly is. From what is presented above it may be concluded that an advanced technology was used to manufacture the roof tiles which may consequently be expected to feature an excellent frost resistance and long service life.

From the results we can also see that the frequency inspection method is a prominent non-destructive testing method being applicable to the evaluation of the fired roof tile structure condition and allowing to predict the frost resistance and service life of these products.

Acknowledgements

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