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Investigation studies involving sound absorbing parameters of roadside screen panels subjected to aging in simulated conditions

Artur Nowoświat *, Jerzy Bochen, Leszek Dulak, Rafał Żuchowski

Faculty of Civil Engineering, Silesian University of Technology, Gliwice, Poland

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ABSTRACT

The paper presents the results of investigation studies involving the impact of atmospheric factors on sound-absorbing parameters of roadside acoustic screen panels. The research studies comprised the aging test consisting of 1000 cycles in simulated conditions, sound absorption measurements and surface morphology tests, using the SEM scanning method. The simulation of aging consisted of 100 or 150 cycles at a time. Then, the panels were investigated in the reverberation chamber to define their sound-absorbing properties. The process was repeated until 1000 cycles were completed. Basing on the carried out tests, a statistical linear model was worked out which was used to estimate the value of a single number sound absorption coefficient after successive aging cycles. The optimality of the model was demonstrated by means of a statistical test confirming normal distribution of random residuals. For the research studies, we employed an innovative structural design of panels for which aging characteristics were obtained. Basing on the obtained results and on the statistical analysis, the prospects to maintain acoustic properties of the panels during their service life was estimated.

1. Introduction

Roadside acoustic screens have been investigated since the late 1950s. The carried out investigation studies have involved principally sound absorption and acoustic effectiveness of the screens which are vital to ensure efficient protection of built-up areas. In order to find out what factors have influence on sound absorption, various aspects were scrutinized, among others such as shielding efficiency [1,2], design and structure of the screen or the type of applied materials [3,4]. Other works [5] have been focused on the analysis of different cross-section types of anti-noise barriers. Also the diffraction process in sound-absorbing partitions have been analyzed [6]. Sound absorption of acoustic screens [7] is one of the main factors determining their efficiency. The main assessment parameters involve such factors as sound absorption coefficient α_{si} [8], weighted sound absorption coefficient α_w, acc. [9] and a single number sound absorption coefficient DL_α acc. [10]. This is a reference platform to define particular absorption classes from the lowest A0 to the highest A5, depending on the value of DL_α coefficient [10]. Usually the tests of acoustic quality are defined for the screens before they are installed. The value of the weighted sound absorption coefficient depends principally on the parameters of the sound-absorbing material. The investigation studies testing the acoustic properties of various fibrous sound-absorbing materials were carried out in work [11]. Work [12] was devoted to the tests on the efficiency of acoustic screens in field conditions, with the edge sound reducer being taken into consideration as an additional contribution of the works. It should be emphasized here that the parameters mentioned above are tested in laboratory conditions without the influence of atmospheric factors or aging factors taken into consideration. The investigation studies involving the change of acoustic properties of screens during their service life are rare. For example, the work [13] demonstrates the impact of the quality of the installation works, presence of seals or other details typical for outdoor installations on the acoustic parameters of the screen. And the work [14] presents novel solutions of sound dissipating screens resistant to atmospheric conditions. The problem of atmospheric aging is investigated when the change of material properties in time is essential [15–21]. It usually involves materials or parts of buildings exposed to the impact of outdoor weather conditions e.g. façade plasters and cladding, roof covering products, windows, plastics, etc. In the same way it involves also roadside acoustic screens. Therefore, we decided to carry out aging tests for the selected acoustic screen panels in simulated conditions as well as the measurements of noise absorption [22,23].

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* Corresponding author.
E-mail address: artur.nowoswiat@polsl.pl (A. Nowoświat).

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Research methods involving the aging process are based principally on the analysis of the changes of material properties in effect of the observations in the natural or artificial conditions. The most reliable results are provided by long-term aging tests in the natural conditions carried out for several years. Such investigation studies have been carried out for many years. For example, in the 1960s in the United Kingdom, Butterworth investigated ceramic materials for 9 years [24]. In the early 1980s Motohoshi and Nireki investigated the durability of the outer masonry layer [25]. At the same time in Sweden, Brolin investigated the durability of doors and windows in the natural weather conditions [26], and in Brazil they investigated for 48 months slabs made of PVC or polyurethane reinforced with fiberglass [27]. In the years following the year 2000 in Hong Kong, the adhesion of façade tiles was investigated [28]. Unfortunately, such investigation studies are time consuming, and therefore there are proposals to facilitate the process by determining the durability on the basis of accelerated aging tests [29–33]. The methods are either short-term tests [34,35] or simulations in specially designed climatic chambers [36–38]. Such climatic chambers are applied to test frost resistance, resistance to moisture or high temperature, to test the resistance to light or UV radiation. Artificial methods are somehow imitating atmospheric impact. Nevertheless, the light sources applied in the chambers in the form of metalohalogen lamps ensure spectrum very similar to the natural sunlight. The application of these tools is principally confined to the testing of paint coats, plastics, building materials, e.g. roof covering materials, sealants or façade materials. During the tests, physical or mechanical parameters are determined [39,40]. It is also advantageous to carry out parallel comparative tests in natural and superficial conditions [19,41,42]. In effect of the tests, we can obtain aging characteristics of the tested materials. They can be later used to work out a formula describing the aging kinetics. This in turn can be used to define the durability curve and to estimate service life if the permissible time of service life is known. In order to find out how the atmospheric factors influence the acoustic properties of roadside screen panels, sound-absorbing tests were carried out for a selected type of panels subjected to the aging test in simulated conditions.

2. Materials and research methods

2.1. Sampling for testing

The aging tests and the tests on acoustic properties were carried out for 4 acoustic panels of the joint area of 11.92 m^2. The panels have a simplified layer arrangement as compared to the designs used earlier and a special outer fabric layer (Fig. 1). The fabric is made of thin fiberglass of circular cross section and diameter of the order of 5-10 μm which forms thin woven ribbons (Fig. 6a). The fabric is well combined with the insulation board made of mineral fibers. The size of the panels is 1.49 × 2.0 m and their joint thickness is 13.0 cm. The casing of the panels is made of L-profiles sized 50 × 50 × 3 (1) and grids on both sides made of steel ribbed bars Φ6 spaced 150 × 150 mm (2) galvanized as the L-profiles. The inside of the panel is filled with mineral wool mats 50 mm thick separated by a cement-bonded particleboard of the thickness 10 mm (5) and shielded from the outside with fiberglass fabrics (3) colored green. From the sound-absorbing side, wool of the density 80 kg/m^3 was applied (4), and on the opposite side wool of the density 120 kg/m^3 (6).

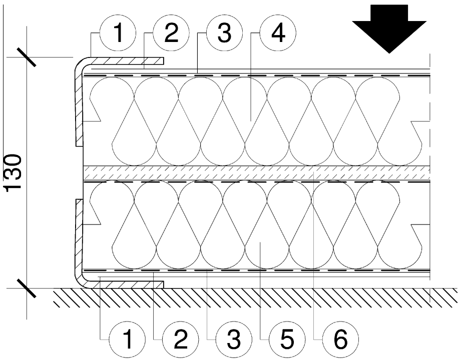

Fig. 1. Layered structure of the acoustic panel.

2.2. Artificial weathering test

To simulate the atmospheric environment, a rotating climatic aging chamber was applied. The stand consists of four chambers (Fig. 2). The core is made by a central rotating chamber which has four exposition walls of the dimensions 1.55 × 2.10 m for mounting the test samples. The three remaining chambers collaborate with the central chamber and simulate the domineering climactic factors. The “sun” chamber presets the radiation close to the natural one. The visible radiation within the wavelength 400–700 nm is ensured by a system of 20 metalohalogen 8 kW lamps generating the temperature of up to +75 °C. An additional system of ultraviolet radiators of the wavelengths 185 and 255 nm imitates the UV radiation. The “rain” chamber simulates rainfall and wind. The amount of fed water and air blasts is regulated with respect to amplitude, frequency and speed. Water is fed from the water supply system and the minerals present in it correspond with the rainwater containing the impurities of the urban environment. The ‘frost” chamber lowers the surface temperature of the investigated elements to −25 °C.

One aging cycle comprises one rotation of the central chamber and lasts 4 × 50 min. The time of the entire 100-cycle test takes 4–5 weeks, depending on the number of cycles per 24 h, which usually takes 4–5 cycles. To ensure similarity, the preset values correspond with average multiannual values. In the research studies, the climate of Upper Silesia was accepted as reference climate. The impact of the “frost” chamber was accepted as the domineering one due to the influence of the temperature of 0 °C being passed through, which is confirmed by the research studies of Pihlajavaara [43] and Basińska [44]. We allowed for the average number of days with freezing–defrosting phenomena, which was 41 days in the year. Hence, the 100 cycles correspond with the period of 2.4 years in the natural climate condition of Upper Silesia. Other relevant multiannual data affecting the durability which were taken into account involve the following: minimum temperature below zero −15.9 °C, maximum temperature in the sun +59 °C for the accepted radiation absorption coefficient of 0.65, the intensity of solar radiation on the vertical plane 839.6 W/m^2, the amount of rainfall on the horizontal plane on windy days 596 mm and the corresponding amount of diagonal rainfall on the vertical plane 335 mm for the average wind speed of 2.8 m/s [45]. The research studies were carried out in two stages. The first stage comprised 450 cycles and impacts of the simulated climate [22]. Due to minimum changes of acoustic parameters, the simulated aging test was prolonged by another 550 cycles within the range of the second stage [23], during which evident changes of acoustic properties were reported.

2.3. Investigation studies on sound absorption

In order to define the influence of the climatic environment on the acoustic properties of the investigated screens, sound absorption measurements were carried out at the initial stage and in time intervals. For that purpose the screens were dismounted from the