Impact of operating conditions on the strength and frequency of destruction of fibre-cement composites

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Abstract: The paper examines the impact of possible operational factors on strength and frequency parameters generated by bending of fibre-cement panels. The tests were performed on elements cut out of a standard commercially available panel. The samples were exposed to factors described as environmental (soaking in water, bath-drying cycles, freeze-thawing cycles) and unique (flame ignition and high temperature exposure) and then subjected to three-point bending tests. Acoustic emission (AE) signals were acquired during the external load application. After the measurements were completed, the strength of individual elements was determined and the frequencies generated during bending were calculated. The obtained results were analysed statistically. Comparing the results obtained for a group of samples subjected to environmental and unique factors, significant differences between them were noted. It was noted that the decrease in the strength of the samples is related to the emission of lower frequency sounds. It was found that the application of the presented methodology allows to determine the condition of the fibre-cement boards in use.

Keywords: fibre-cement composites, ventilated façades, acoustic emission method, bending strength

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1. Introduction

Fibre-cement cladding panels are a material known in construction for years. Currently, it is experiencing a renaissance because it is safe for health and has extraordinary aesthetic qualities that give the building an original look [1-2].

In the 1970s and 1980s, asbestos, which proved to be a carcinogenic material, was used to produce fibre cement and steps were taken to eliminate the harmful component. Currently, fibre-cement cladding panels are made from Portland cement with the addition of synthetic cellulose fibres. Cement accounts for 90% of the production mixture and is responsible for the binding of the material and its final durability. Cellulose makes only 10% of fibre-cement cladding panels. It is gap filler and additive that provides the right amount of water in the cement setting process. It also increases the density of the final product. To improve the appearance and flexibility of fibre-cement panels, mineral substances are also added to them [3-5].

The mixture of these materials is layered in the production process and then pressed. The production technology allows obtaining highly-durable fibre-cement panels. The façade made in this system does not harm the environment, as the material is completely recycled [6-8].

Installation of the fibre-cement cladding panels does not require any wet work, which makes it possible to plan the works at any time of the year. Cladding panels are usually laid on the insulation layer, fixing them to the previously prepared system grid substrate. When installing the cladding on the façade, remember to move the panels away from the insulation layer, and to leave the vent holes. Fibre-cement panels on façades can be used for new buildings as well as for renovation of existing buildings [9-10].

Fibre-cement cladding elements used on façades are exposed to characteristic operating conditions (storing conditions). The panels are periodically soaked and dried and are exposed to the freeze-thawing process. Building façades are also exposed to UV radiation. Moreover, during the service life of fibre-reinforced cement elements, exceptional situations related to fire and high temperatures may occur. Therefore, it is considered appropriate to conduct tests on fibre-cement elements reflecting the indicated conditions[11-12].

The majority of studies on fibre-cement panels to date have been devoted to the impact of operational factors [13–15] and high temperatures, tested by examining the physicochemical parameters of the panels, mainly their bending strength (MOR). The article of Ardanuy et al [4] presents the results of tests, among others, on the impact of high temperature on fibre-cement panels, but only in relation to the bending strength MOR. Li et al. [16] studied the impact of high temperatures on the composites.
produced by extrusion but also solely on the basis of their mechanical properties. Non-destructive testing of fibre-cement panels was mainly limited to the detection of imperfections arising at the production stage. The works of Drelich et al [17] and Schabowicz and Gorzelanieczyk [18] presented the possibility of using Lamb waves in a non-contact ultrasonic scanner to detect defects in fibre-cement panels at the production stage. The article [19] by Stark describes the method of delamination detection in composite using a moving ultrasonic probe. The works of Berkowski et al [20], Hoła and Schabowicz [21] and Davis et al. [22] the impact-echo method was proposed together with the impulse response method for delamination identification in fibre-cement elements. However, when analysing the results, it was found that due to the fact that the impulse response method is used to test elements thicker than 100 mm, it does not give unambiguous results in testing fibre-cement panels. Preliminary tests also proved that hitting the board with a hammer can cause damage, which is another reason why the impulse response method is not suitable for fibre-cement panels. Also, the impact-echo method is not recommended for testing standard fibre-cement panels as it has been reported that multiple reflections of waves cause interference, which makes the interpretation of the obtained image difficult [20]. It is therefore determined that this method is reliable for fibre-cement panels thicker than 8 mm.

There is little information in the literature on the use of other non-destructive testing methods for fibre-cement panels. Research described in Chady et al. [23] and Chady and Schabowicz [24] demonstrated that the terahertz method (T-Ray) is suitable for testing fibre-cement panels. The terahertz signals are very similar to ultrasonic signals, but their interpretation is more complicated. In the paper [25], the microtomography method was used to identify delamination and low-density areas in fibre-cement panels. The test results indicated that this method clearly reveals the differences in the microstructure of the panels and can therefore be a useful tool for testing the structure of fibre-cement panels, where defects may occur due to production errors. A disadvantage of the methodology may be that it can only be used for small elements. It should be noted that so far, few cases of testing fibre-cement panels by means of acoustic emission have been reported in the literature. Ranachowski, Schabowicz et al. conducted pilot studies on fibre-cement panels produced by extrusion, including those exposed to high temperature, in which the acoustic emission method was used to determine the impact of cellulose fibres on the panel strength and attempts were made to distinguish AE events emitted by fibres and matrix. The results of these tests confirmed the usefulness of this method for testing fibre-cement panels. The works [26] of Gorzelanieczyk et al. proposed to use the acoustic emission method to investigate the impact of high temperature on fibre-cement panels. It should be mentioned that the impact of high temperatures on concrete and
the interdependencies related to this type of impact have been extensively described using the acoustic emission method; example is work [27] by Ranachowski. Moreover, the acoustic emission method is successfully used in the testing low thickness materials, for example steel elements and polymer-based composites [28]. The indicated methodology is also used in the testing of food products with considerable tenderness [29].

It should remembered that, in addition to the effects of heat and fire, one of the most damaging factors for many construction products, in particular composite products containing reinforcement in the form of different fibres, especially organic fibres (such as cellulose fibres), is the effect of negative temperatures. Studies using acoustic emission were performed also in the works [30-33]. Therefore, the authors state that it is possible to link the frequency of generated acoustic emission signals with the strength parameters of fibre-cement panels.

2. Materials and methods

Testing on fibre cement panels was conducted for the elements exposed to environmental and unique factors for the following test cases:

- air-dry condition (no destruction, reference);
- soaking in water for 1 hour;
- soaking in water for 24 hour;
- 25 bath-drying cycles;
- 50 bath-drying cycles;
- 10 freeze-thaw cycles;
- 25 freeze-thaw cycles;
- 50 freeze-thaw cycles;
- 100 freeze-thaw cycles;
- direct exposure to flame (resulting in a temperature of up to 400\(^\circ\)C) for 2.5 minutes;
- direct exposure to flame (resulting in a temperature of up to 400\(^\circ\)C) for 5 minutes;
- direct exposure to flame (resulting in a temperature of up to 400\(^\circ\)C) for 7.5 minutes;
- direct exposure to flame (resulting in a temperature of up to 400\(^\circ\)C) for 10 minutes;
- the temperature of 230\(^\circ\)C for 3 hours.

The first-case panels – reference, were stored in constant laboratory conditions (+23\(^\circ\)C, 60% humidity).
Samples from 2-3 series were immersed in water at room temperature (approx. 23°C) for 1 hour and 24 hours respectively and then subjected to wet bend tests.

Bath-drying cycles (4-5 cases) were conducted by alternately immersing the samples in water at an ambient temperature higher than 5°C (for approx. 23°C) 18 hours and drying in a ventilated dryer at temperature 60°C (±5°C) and relative humidity less than 20% for 6 hours. The number of cycles depended on the test case.

Cyclic freeze-thawing (6-9 cases) was performed in an air-water environment by alternate cooling (freezing) in a freezer −20°C (±2°C) for 2 hours and keeping at this temperature for another hour and heating (thawing) in a water bath at this temperature 20°C (±2°C) for two hours and keeping at this temperature for another hour. During the cooling and heating (freezing and thawing) cycles, the samples were laid out in such a way as to ensure free circulation of the conductive medium (air in the freezer or bath water).

Fire is an exceptional factor characterised by a high temperature, occurring, among others, during a fire. The destruction of fibre-cement panels consisted in applying a flame of approx. 400°C for 2.5 to 10 minutes, tested at intervals of 2.5 minutes (10-13 cases).

Fibre-cement panels were burned out in the laboratory furnace at a temperature of 230°C for 3 hours at which the cellulose fibres are degraded. The choice of appropriate temperature and burn-up time was determined on the basis of the literature on the impact of temperatures on cellulose, as well as own preliminary and foreign studies, in order to achieve complete destruction of the fibres contained in the plates.

All test samples were cut out of a 310×125 cm factory panel. The dimensions of each tested element were 30×5×0.8 cm. The test samples were subjected to three-point bending tests. The settling velocity of the load mandrel was 0.1 mm/min. The axial distance between the support points was 20 cm and the radius of the supports and mandrel was 1 cm. Acoustic emission signals were acquired during each bending test. For this purpose, two sensors with built-in preamplifiers with 25-80 kHz and 100-450 kHz measuring ranges were mounted on the sample surface near the supports (Figure 1).

The tested fiber cement boards were produced using the Hatschek process. The basic mixture consisted of cement, sand, cellulose and water (autoclave drying). The raw material used for the production of air-dried fiber cement consists for the most part of a binder - Portland cement. In order to optimize the properties of this product, additional materials such as powdered lime are added to it. The production process of the panels follows the described cycle. After the materials are mixed together, a suspension forms. The liquid mixture is delivered to a vat containing rotating mesh rollers.
The rollers collect the solids by removing some of the water. The tape moving along the surface of the rolls collects a thin layer of fiber cement that forms on each of them. The accumulated layered plate is moved to vacuum drainage devices which remove most of the water. By means of the belt, the wet mass is transferred to the forming drum, on which subsequent layers are applied until the required thickness is achieved. After obtaining the appropriate thickness of the sheet, the built-in automatic cutting knife of the forming drum is turned on, and the raw board is placed on the conveyor and then placed on a stack. The stacked damp plates are separated by steel sheets. The stacked plates are then transferred to a press that exerts a pressure of at least 12,000 tons. As a result, the boards are compact and have a high density. Then the plates are dried.

![Fig. 1. View of the test bench.](image)

After the tests, the bending strength of the samples and the average frequency values of AE signals generated during the tests were analysed. The bending stresses were determined according to the formula [34]:

\[
\frac{3 \cdot F \cdot l}{2 \cdot b \cdot h^2}
\]

F – load/force [N];

l – span in the axes of support [mm];

f – maximum deflection [mm];
b – sample width [mm];

h – sample thickness [mm];

a – the distance between the axis of support and the axis of load application [mm].

The average frequency values before the moment of destruction were recorded and read using processor and Vallen AE software.

The data obtained during the tests were analysed statistically and the impact of particular factors on the obtained results was determined.

3. Results and discussion

<table>
<thead>
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<th>Parameter</th>
<th>Test case</th>
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<th>Mean</th>
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<th>Max</th>
<th>Standard deviation</th>
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<td>24.845</td>
<td>23.440</td>
<td>27.190</td>
<td>1.2527</td>
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<td>3</td>
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<td>25.033</td>
<td>24.845</td>
<td>23.440</td>
<td>27.190</td>
<td>1.2527</td>
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IBM SPSS Statistics 26 was used to analyse the data presented. The significance level was taken as 0.05. The Shapiro-Wilk test was chosen to test the standard distribution and the Levene test to test the homogeneity of variance. Due to the lack of standard distribution for some data and the lack of homogeneity of variance in most cases, a group of non-parametric tests for independent variables were used to compare mean distributions, in particular the test for many Kruskal-Wallis groups. First, all data were pre-tested in order to select the appropriate test groups to examine the data. The groups examined are approximately equinumerous. Therefore, standard distributions of data in individual groups were studied with the Shapiro-Wilk test. For most data, there are no grounds to reject the hypothesis of standard distribution. The Levene test was then performed to examine the homogeneity of variance. In most groups there is no homogeneous variance. Therefore, in order to examine the distributions, it was decided to use the non-parametric test for Kruskal-Wallis independent variables.

Data distributions for bending strength MOR [MPa] differ statistically significantly in individual groups ($T=131,185, p=0,000$). In the next step, a post-hoc Bonferroni test was performed to see where there are significant differences.

<table>
<thead>
<tr>
<th>Average event frequency $EA$ before reaching $F_{\text{max}}$ [kHz]</th>
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<td>1</td>
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<td>572.800</td>
<td>566.500</td>
<td>492.000</td>
<td>673.000</td>
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<td>2</td>
<td>10</td>
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<td>563.000</td>
<td>424.000</td>
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<tr>
<td>4</td>
<td>10</td>
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<td>520.000</td>
<td>473.000</td>
<td>569.000</td>
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<tr>
<td>5</td>
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<td>418.500</td>
<td>316.000</td>
<td>517.000</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>519.500</td>
<td>512.500</td>
<td>425.000</td>
<td>621.000</td>
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<tr>
<td>7</td>
<td>10</td>
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<td>492.000</td>
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<tr>
<td>8</td>
<td>10</td>
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<td>427.000</td>
<td>376.000</td>
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<tr>
<td>9</td>
<td>10</td>
<td>385.700</td>
<td>376.500</td>
<td>291.000</td>
<td>505.000</td>
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<tr>
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<td>245.000</td>
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<td>10</td>
<td>167.000</td>
<td>161.500</td>
<td>119.000</td>
<td>237.000</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>142.200</td>
<td>140.000</td>
<td>87.000</td>
<td>203.000</td>
</tr>
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</table>
For sample 1 the results are significantly higher (significantly higher average) than for samples 5, 7, 8, 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 2, 3, 4, 6.

For sample 2 the results are significantly higher (significantly higher average) than for samples 5, 7, 8, 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 3, 4, 6.

For sample 3 the results are significantly higher (significantly higher average) than for samples 5, 7, 8, 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 2, 4, 6.

For sample 4 the results are significantly higher (significantly higher average) than for samples 5, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 2, 3, 6, 7, 8, 9.

For sample 5 the results are significantly higher (significantly higher average) than for samples 13, 14, significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 6 and do not differ statistically significantly from the results for samples 7, 8, 9, 10, 11, 12.

For sample 6 the results are significantly higher (significantly higher average) than for samples 5, 7, 8, 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 2, 3, 4.

For sample 7 the results are significantly higher (significantly higher average) than for samples 10, 12, 13, 14, 14 significantly lower (significantly lower average) than for samples 1, 2, 3, 6 and do not differ statistically significantly from the results for samples 4, 5, 8, 9, 11.

For sample 8 the results are significantly higher (significantly higher average) than for samples 10, 12, 13, 14, significantly lower (significantly lower average) than for samples 10, 12, 13, 14 and do not differ statistically significantly from the results for samples 4, 5, 7, 9, 11.

For sample 9 the results are significantly higher (significantly higher average) than for sample 12, 13, 14, significantly lower (significantly lower average) than for samples 1, 2, 3, 6, and do not differ statistically significantly from the results for samples 4, 5, 7, 8, 10, 11.

For sample 10 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 6, 7, 8, and do not differ statistically significantly from the results for samples 5, 9, 11, 12, 13, 14.
For sample 11 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 6, are significantly higher (significantly higher average) than for sample 14 and do not differ statistically significantly from the results for samples 5, 7, 8, 9, 10, 12, 13.

For sample 12 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 6, 7, 8, 9, and do not differ statistically significantly from the results for samples 5, 10, 11, 13, 14.

For sample 13 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 5, 6, 7, 8, 9, and do not differ statistically significantly from the results for samples 10, 11, 12, 14.

For sample 14 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 5, 6, 7, 8, 9, 11 and do not differ statistically significantly from the results for samples 10, 3, 12, 13.

Fig. 2. Graphical representation of the results of the Kruskal-Wallis test for MOR bending strength.

Data distributions for the average frequency of EA events before reaching Fmax differ in individual groups in a statistically significant manner (T=116.902, p=0.000). In the next step, a post-hoc Bonferroni test was performed to see where there are significant differences.
• For sample 1 the results are significantly higher (significantly higher average) than for samples 5, 8, 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 2, 3, 4, 6, 7.

• For sample 2 the results are significantly higher (significantly higher average) than for samples 5, 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 3, 4, 6, 7, 8.

• For sample 3 the results are significantly higher (significantly higher average) than for samples 5, 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 2, 4, 6, 7, 8.

• For sample 4 the results are significantly higher (significantly higher average) than for samples 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 2, 3, 5, 6, 7, 8.

• For sample 5 the results are significantly higher (significantly higher average) than for samples 11, 12, 13, 14, significantly lower (significantly lower average) than for samples 1, 2, 3 and do not differ statistically significantly from the results for samples 4, 6, 7, 8, 9, 10.

• For sample 6 the results are significantly higher (significantly higher average) than for samples 9, 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 2, 3, 4, 5, 7, 8.

• For sample 7 the results are significantly higher (significantly higher average) than for samples 10, 11, 12, 13, 14, and do not differ statistically significantly from the results for samples 1, 2, 3, 4, 5, 6, 8, 9.

• For sample 8 the results are significantly higher (significantly higher average) than for samples 10, 11, 12, 13, 14, significantly lower (significantly lower average) than for samples, 3 and do not differ statistically significantly from the results for samples 2, 3, 4, 5, 6, 7, 9.

• For sample 9 the results are significantly higher (significantly higher average) than for sample 1, 2, 3, 4, 6, and do not differ statistically significantly from the results for samples 5, 7, 8, 10, 11.

• For sample 10 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 6, 7, 8, and do not differ statistically significantly from the results for samples 5, 9, 11, 12, 13, 14.

• For sample 11 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 5, 6, 7, 8 and do not differ statistically significantly from the results for samples 9, 10, 12, 13, 14.
For sample 12 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 5, 6, 7, 8, 9, and do not differ statistically significantly from the results for samples 10, 11, 13, 14.

For sample 13 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 5, 6, 7, 8, 9, and do not differ statistically significantly from the results for samples 10, 11, 12, 14.

For sample 14 the results are significantly lower (significantly lower average) than for samples 1, 2, 3, 4, 5, 6, 7, 8, 9, and do not differ statistically significantly from the results for samples 10, 11, 12, 13.

4. Discussion

On the basis of the presented tests and the results obtained, it was found that some operating factors significantly affect both the value of bending strength and frequency of AE signals recorded before the moment of destruction. The greatest impact on the analysed parameters has bath-drying cycles, cyclic freeze-thawing, direct fire and high temperature effects. Chronic bathing and drying (5 series)
reduces the frequency of recorded AE signals and the bending strength at 50 cycles by up to 30%. Passing through the value 0°C (6-9 series) also causes a visible decrease in the frequency of the generated sounds and the bending strength values. The increase in the number of freeze-thaw cycles reduces the frequency of sounds and strength parameters by up to half. For the discussed test cases, the situation was associated with a reduction in the degree of binding between the fibres and the matrix caused by environmental factors. In turn, for samples from groups exposed to flame (10-13 series) and high temperature (14 series), the decrease in these parameters was even 80%. For these cases, the reduction of both parameters was associated with structure degradation and burn-up of reinforcement fibres.

5. Conclusion

The paper presents the results of three-point bending tests for fibre-cement elements subjected to environmental and unique factors with simultaneous acquisition of AE signals. The bending strength values and frequencies generated before the moment of destruction were analysed. Based on the results obtained, the following conclusions are drawn:

- The reduction of strength of fibre-cement elements is associated with the generation of lower bending frequencies for samples with unchanged mechanical parameters.
- The application of the acoustic emission method enables the tracking of frequencies associated with the formation of various types of changes in the material structure.
- The fibre-cement board structure destruction process is a complex mechanism, closely related to the presence of reinforcing fibres and the degree of bond between the reinforcement and the matrix.
- The frequencies generated by the changes in the fibre-cement structure are closely related to the presence of the fibre reinforcement and the degree of bond between the reinforcement and the matrix.
- The application of the acoustic emission method enables effective detection and monitoring of the initiation of changes in the structure affecting the reduction of mechanical parameters of the panels.
- The results obtained give the possibility to apply the AE method to assess the condition of full-sized fibre-cement elements.
References


[34] 34. PN EN 12467 FIBRE-CEMENT FLAT SHEETS - PRODUCT SPECIFICATION AND TEST METHODS

Wpływ warunków eksploatacyjnych na wytrzymałość i częstotliwości niszczenia kompozytów cementowo-włóknistych

Słowa kluczowe: kompozyty cementowo-włókniste, elewacje wentylowane, metoda emisji akustycznej, wytrzymałość na zginanie

Streszczenie: Badania płyt włóknisto-cementowych przeprowadzono dla elementów podanych działaniu czynników eksploatacyjnych o charakterze środowiskowym i wyjątkowym dla następujących przypadków badawczych:

- staniu powietrza suchego (brak destrukcji, stan odniesienia, referencyjny);
- nasączenia w wodzie przez 1 godzinę;
- nasączenia w wodzie przez 24 godziny;
- 25 cykli kąpieli-suszenia;
- 50 cykli kąpieli-suszenia;
- 10 cykli zamrażania-rozmrażania;
- 25 cykli zamrażania-rozmrażania;
Do analizy przedstawionych danych użyto programu IBM SPSS Statistics 26. Jako poziom istotności przyjęta została wartość 0,05. W celu zbadania normalności rozkładów wybrano test Shapiro-Wilka, a do zbadania homogeniczności wariancji test Levene’a. W związku z brakiem rozkładu normalnego dla niektórych danych oraz z brakiem homogeniczności wariancji w większości przypadków, do porównywania między sobą rozkładów średnich użyto grupy testów nieparametrycznych dla zmiennych niezależnych, w szczególności testu dla wielu grup Kruskala-Wallisa.

Rozkłady danych dla wytrzymałości na zginanie MOR [MPa] różnią się w poszczególnych grupach w sposób statystycznie istotny (T=131,185, p=0,000). W następnym kroku przeprowadzono test post-hoc Bonferroniego w celu sprawdzenia, w których przypadkach zachodzi istotne różnice.

Na podstawie przedstawionych badań i otrzymanych rezultatów stwierdzono, że niektóre czynniki eksploatacyjne w sposób znaczący wpływają zarówno na wartość wytrzymałości na zginanie, jak i częstotliwości sygnałów AE rejestrowanych przed momentem zniszczenia. Na podstawie przedstawionych badań i otrzymanych rezultatów stwierdzono, że niektóre czynniki eksploatacyjne w sposób znaczący wpływają zarówno na wartość wytrzymałości na zginanie, jak i częstotliwości sygnałów AE rejestrowanych przed momentem zniszczenia. Na podstawie przedstawionych badań i otrzymanych rezultatów stwierdzono, że niektóre czynniki eksploatacyjne w sposób znaczący wpływają zarówno na wartość wytrzymałości na zginanie, jak i częstotliwości sygnałów AE rejestrowanych przed momentem zniszczenia. Na podstawie przedstawionych badań i otrzymanych rezultatów stwierdzono, że niektóre czynniki eksploatacyjne w sposób znaczący wpływają zarówno na wartość wytrzymałości na zginanie, jak i częstotliwości sygnałów AE rejestrowanych przed momentem zniszczenia. Na podstawie przedstawionych badań i otrzymanych rezultatów stwierdzono, że niektóre czynniki eksploatacyjne w sposób znaczący wpływają zarówno na wartość wytrzymałości na zginanie, jak i częstotliwości sygnałów AE rejestrowanych przed momentem zniszczenia. Na podstawie przedstawionych badań i otrzymanych rezultatów stwierdzono, że niektóre czynniki eksploatacyjne w sposób znaczący wpływają zarówno na wartość wytrzymałości na zginanie, jak i częstotliwości sygnałów AE rejestrowanych przed momentem zniszczenia.
W artykule przedstawiono wyniki testów trzypunktowego zginania dla elementów włóknisto- cementowych poddanych działaniu czynników środowiskowych i wyjątkowych z jednoczesną akwizycją sygnałów AE. Analizie poddano wartości wytrzymałości na zginanie oraz częstotliwości generowanych przed momentem zniszczenia. Na podstawie otrzymanych wyników wyciągnięto następujące wnioski:

- Obniżenie wytrzymałości elementów włóknisto-cementowych wiąże się z generowaniem niższych częstotliwości przy zginaniu w odniesieniu do próbek o niezmienionych parametrach mechanicznych.
- Zastosowanie metody emisji akustycznej umożliwia śledzenie częstotliwości powiązanych z powstawaniem różnego rodzaju zmian w strukturze materiału.
- Przebieg procesu niszczenia struktury płyty cementowo-włóknistej jest mechanizmem złożonym i powiązanym w sposób ścisły z obecnością włókien zbrojących oraz stopniem wiązania pomiędzy zbrojeniem a matrycą.
- Częstotliwości generowane przez zmiany zachodzące w strukturze włókno-cementu są ścisłe powiązane z obecnością zbrojenia w postaci włókien oraz stopniem wiązania między zbrojeniem a matrycą.
- Zastosowanie techniki emisji akustycznej umożliwia skuteczne wykrywanie i monitorowanie inicjacji zmian w strukturze wpływających na obniżenie parametrów mechanicznych płyt.
- Otrzymany rezultaty dają możliwość zastosowania metody AE do oceny stanu pełnowymiarowych elementach cementowo-włóknistych.

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