EVALUATION OF THREE POINT BENDING TEST ON DIFFERENT FINE-GRAINED COMPOSITES USING ACOUSTIC EMISSION METHOD

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ABSTRACT

The paper describes the use of acoustic emission method, a non-destructive testing tool applied to three-point bending testing of fine-grained composites. While its application to homogenous materials in mechanical engineering is described quite well, its employ and evaluation in civil engineering are very complicated because many building materials are not as homogenous as fine-grained composites. Acoustic emission procedures show results similar to other classical techniques. Although rather costly, the acoustic emission method has the advantage of an easy application to the monitored structure.

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Key words: acoustic emission, fine-grained composites, civil engineering, three-point bending test, non-destructive testing
1. Introduction

The acoustic emission method is a widely used non destructive technique for detecting crack growth on metal materials. [1] However, this method is also used to monitor the behaviour of building materials. The changes in the material brought about by loading generate stress waves. Such waves can be detected by an acoustic emission system. [2] Due to the formation and growth of microcracks in the material structure, a number of acoustic emission events of different amplitudes, time durations, and acoustic emission energies are released. [3] A typical acoustic emission signal is shown in Fig. 1.

![Fig. 1: A typical acoustic emission signal](image)

This article aims to determine the behaviour of three-point bending laboratory experiments of concrete beams by applying the acoustic emission method. [4] As shown in Fig. 2, the specimens have a rectangular cross-section (w x h) with an effective span (L) equal to three times the section height (h). A notch (a) of one-third of the beam height (h) was made in the mid-section of the span.[5]

![Fig. 2: A three point bending test](image)

2. Experimental set up

The three-point bending tests were performed on notched beams with a square cross section of 100 mm × 100 mm and length of 400 mm as shown in Fig. 1. A notch with a depth of 33 mm was placed in the centre of the beam. The effective span was 300 mm. The mixtures of both monitored
types of concrete specimens are shown in Tab. 1. They mainly differ in the amount of coarse aggregate. The Heckert FPZ 100/1 testing machine was used for three-point bending fracture tests of concrete specimens. The acoustic emission measurements were carried out by the acoustic emission measuring system XEDO made by DAKEL (Czech Republic) with four acoustic emission sensors of type MIDI (made by DAKEL) attached to the surface. Fig. 3 shows a photo of the actual measurement with the location of acoustic emission sensors. The specimens measured at a temperature of 20°C were degraded by temperatures shown in Fig. 4.

![Fig. 3: The real experimental set up](image)

Table 1: Concrete mixtures (kg/m³)

<table>
<thead>
<tr>
<th>MIXTURE</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement CEM I 42.5R</td>
<td>345</td>
<td>345</td>
</tr>
<tr>
<td>Sand 0/4</td>
<td>848</td>
<td>813</td>
</tr>
<tr>
<td>Coarse aggregate 8/16</td>
<td>980</td>
<td>0</td>
</tr>
<tr>
<td>Coarse aggregate 11/22</td>
<td>0</td>
<td>1010</td>
</tr>
<tr>
<td>Water</td>
<td>160</td>
<td>176</td>
</tr>
<tr>
<td>Superplasticizer</td>
<td>2.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

3. Results

Time histories (t) up to the maximal force of acoustic emission activities (AE) and of loading (F) of both mixtures (see Tab. 1) at seven degrading temperatures are shown in Fig. 4.
Fig. 4 The acoustic emission activity of mixture A (left) and mixture B (right)

The better properties of specimens made from mixture B (see Tab. 1) are shown in Fig. 5. Since, in both specimens, the strength of a three point bending shows similar values at temperatures between 20 °C and 200 °C, apparently, the heating of a concrete specimen up to a temperature of 200 °C has no influence on its mechanical properties.
Fig. 5: The dependence of the strength of three point bending $f_{cf}$ (left) and of nominal strength $f_{ct}$ (right) on the degraded temperature $T$.

The results of the acoustic emission activities $N_{AC}$ up to maximum load are shown in Fig. 6.

Fig. 6: The acoustic emission activity $N_{AE}$ of two tested concrete mixtures (see Tab. 1) at the different degraded temperatures $T$.

The graph in Fig. 6 demonstrates the activity of acoustic emission in each thermal degradation phase. A higher acoustic emission activity in the sample is caused by the material being able to resist fracture. Thus, a higher acoustic emission activity indicates the material being stronger. In view of this, it can be concluded that, while at a firing temperature of up to $400 \, ^\circ C$, the strength of mixture A remains the same, at firing temperatures of $600 \, ^\circ C$ and $800 \, ^\circ C$, the material becomes a little fragile with the highest fragility achieved at a firing of $1000 \, ^\circ C$. At $1200 \, ^\circ C$, the inner structure
of the material already changes substantially restoring the previous strength. In mixture B, due to its coarser aggregate, the strength measured by acoustic emission is increased up a temperature of 800 °C. With firing from 1000 °C to 1200 °C, this material becomes substantially more fragile as compared with the firing temperatures.

4. Conclusion

Comparing the acoustic emission activity values in three-point bending, we see that, the addition of coarse aggregate to the mixture will increase the strength at higher firing temperatures resulting in a longer endurance in case of fire.

5. Acknowledgement

This outcome has been achieved with the financial support of the Czech Science Foundation, project No. 16-18702S (AMIRI), and supported by the Ministry of Education, Youth and Sports of the Czech Republic under the “National Sustainability Programme I” (project No. LO1408 AdMaS UP) and project No. FAST-J-17-4554 supported by Faculty of Civil Engineering of Brno University of Technology.

6. References