ACOUSTICALLY ASSESSED INFLUENCE OF AIR PORE STRUCTURE ON FAILURE OF SELF-COMPACTING CONCRETES UNDER COMPRESSION

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Abstract. The paper presents the results of investigations into the influence of pore structure on the failure of self-compacting concretes modified with superplasticizers commonly used in construction. Pore structure examinations were carried out in practically the whole range of pore diameters by means of an image analyzer and a mercury porosimeter. The failure of the self-compacting concretes under compression, was investigated by the acoustic emission technique and other methods. The levels of cracking initiating stress $\sigma_i$ and critical stress $\sigma_{cr}$, demarcating the different stages in the failure process, were determined. It has been shown that there is a relationship between the pore structure parameters and the levels. The fatigue strength of the self-compacting concretes was calculated from the experimental results and on this basis the suitability of the concretes for structures subject to cyclic loads was determined.

Keywords: self-compacting concrete, pore structure, failure, compression, acoustic emission, ultrasounds.

1. Introduction

Self-compacting concretes are increasingly often used to erect buildings and civil engineering structures (Klug,!Holschemacher 2003; Holschemacher 2004; Okamura, Ouchi 1994, 2003; Okamura et al. 2005). Concrete mixes used for this purpose are modified with superplasticizers based on different chemical components and producing a similar rheological effect. But the question arises: does the air pore structure in hardened self-compacting concretes depend on the added superplasticizer? If so, does this structure affect the failure of the concrete? The answers to these questions can be useful in, for example, predicting the performance of self-compacting concrete in service. This applies particularly to concrete built into structures subject to cyclic loads, such as bridge deck slabs, industrial floors and concrete road surfaces. Therefore it seems interesting and desirable to examine the failure of such concretes and determine the levels of cracking initiating stress $\sigma_i$ and critical stress $\sigma_{cr}$, demarcating the different stages in this process. It is generally accepted that these properties have a bearing on the durability of concrete (Błaszczyński 2011; Furtak 2002; Hoła 1992, 2000b; New- man, K., Newman, J. B. 1971; Ngab et al. 1981), but little is known about the course of this process in self-compacting concretes.

Considering the above, the air pore structure of several self-compacting concretes made with additions of two most commonly used superplasticizers was examined. Then the failure of the concretes was investigated using acoustic techniques and the levels of cracking initiating stress $\sigma_i$ and critical stress $\sigma_{cr}$, demarcating the different stages in this process, were determined. The results were used to calculate the fatigue strength of the concretes. On this basis the authors drew a conclusion about the suitability of the concretes for structures subject to cyclic loads. It should be mentioned that the proof that the fatigue strength of concrete depends on the levels of cracking initiating stress $\sigma_i$ and critical stress $\sigma_{cr}$ can be found in the literature (Beres 1971; Flaga 1995; Furtak 1997; Hsu 1981).

2. Investigations

Four self-compacting concretes, denoted as: A/S, B/S, C/S and D/S, made of the same components, i.e. Portland cement CEM I 42.5 R, gravel aggregate, river sand, fly ash (chemical composition of the fly ash: SiO$_2$ 51%, Al$_2$O$_3$ 24%, Fe$_2$O$_3$ 6.8%, CaO 0.3%, S0 0.5%; power plant based on hard coal), drinking tap water and two different superplasticizers were subjected to tests. The maximum aggregate grading was 16 mm for concretes A/S and C/S and 8 mm for concretes B/S and D/S. Superplasticizer S$_A$ was added to make concretes A/S and B/S, while concretes C/S and D/S were made using superplasticizer S$_V$. Superplasticizer S$_A$ was based on polycarboxylic ether while superplasticizer S$_V$ was based...
Table 1. Compositions of designed self-compacting concrete mixes and average compressive strengths $f_{cm}$ of concretes produced from them

<table>
<thead>
<tr>
<th>Mix and concrete symbol</th>
<th>Concrete mix composition [kg/m$^3$]</th>
<th>Water-binder ratio $W/(C+P)$</th>
<th>Sand content [%]</th>
<th>Average compressive strength $f_{cm}$ after 90 days of curing [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/S$\alpha$</td>
<td>1064 581 355 143 164 3.15 0.34 35.3</td>
<td>44.5 4.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B/S$\alpha$</td>
<td>896 747 325 109 195 3.25 0.45 45.5</td>
<td>32.4 4.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C/S$\gamma$</td>
<td>1064 581 355 143 164 4.18 0.34 35.3</td>
<td>59.2 5.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/S$\gamma$</td>
<td>896 747 325 109 195 4.25 0.45 45.5</td>
<td>41.8 5.8%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*) Note: the variation coefficient value

Table 2. Determined rheological properties of concrete mixes

<table>
<thead>
<tr>
<th>Test method</th>
<th>Tested parameter</th>
<th>Requirements acc. to Li and Hwang (2003), Nagamoto and Ozawa (1999), Okamura and Ouchi (2003), European Project Group (2005)</th>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrams cone</td>
<td>500 mm diameter spread time $T_{500}$ [s]</td>
<td>2–5</td>
<td>A/S$\alpha$</td>
</tr>
<tr>
<td></td>
<td>Spread diameter $r$ [mm]</td>
<td>650–800</td>
<td>B/S$\alpha$</td>
</tr>
<tr>
<td>J-Ring</td>
<td>Difference between measured spread diameters $</td>
<td>d_1 - d_2</td>
<td>$ [mm]</td>
</tr>
<tr>
<td>L-Box</td>
<td>Ratio of measured heights $H_2/H_1$ [–]</td>
<td>0.80–1.00</td>
<td>D/S$\gamma$</td>
</tr>
</tbody>
</table>

The failure process was investigated using an Instron 1126 strength tester and two acoustic techniques (Hola, Schabowicz 2010), i.e. the ultrasonic technique and the acoustic emission technique. 100×100×100 mm concrete samples were used in the ultrasonic investigations. Longitudinal ultrasonic wave velocity $V_L$ was the investigated parameter, determined (perpendicularly to the direction of load action) as a function of compressive strength. An UNIPAN 543 ultrasonic probe with digital readout, and 100 kHz ultrasonic heads were used in the investigations. 50×50×100 mm samples (cut out from larger test pieces) were used in the acoustic emission investigations. As they were being compressed, the following AE descriptors were recorded: rate of events $N_{se}$ and RMS signal. Friction at the contact between the specimen’s surface and the strength tester’s pressure plates was eliminated by grinding the surfaces to ensure their mutual parallelism with accuracy to 0.05 mm and then greasing them. A Vallen-Systeme Gmbh AMS3 measuring set and two VS 150-M sensors with a transmission band of 100–450 kHz were used in the investigations. Fig. 3 shows the AE measurement rig.

on a combination of polycarboxylates and viscosity, setting and hardening regulators. The two superplasticizers are used in construction practice to make self-compacting concrete mixes.

The compositions of the designed concrete mixes are shown in Table 1. The latter also includes average compressive strengths $f_{cm}$ of the concretes produced from the mixes, determined on 150×150×150 mm samples after 90 days of curing in a climate chamber at an air temperature of $+18 \degree C$ ($\pm 1 \degree C$) and a relative air humidity of 95% ($\pm 5\%$).

The concrete mixes were tested to determine their basic rheological properties, using the Abrams cone, the J-Ring method and the L-Box method. The results of the tests are shown in Table 2. Fig. 1 shows exemplary J-Ring spread test results for mix A/S$\alpha$ (Fig. 1a) and L-Box flow tests results for mix D/S$\gamma$ (Fig. 1b). The tests confirmed that the rheological properties of the designed concrete mixes met the requirements for self-compacting mixes (Li, Hwang 2003; Nagamoto, Ozawa 1999; Okamura, Ouchi 2003; European Project Group 2005). It also became apparent that despite the fact that they differed in their superplasticizers and maximum aggregate grading (16 and 8 mm), the mixes were characterized by very similar rheological properties.

The air pore structure in the four hardened 90-day old concretes was examined in a diameter range of 10–4000 µm by means of a computer image analyzer Image Pro Plus 4.1 (Fig. 2a) and in a radius range of 5–7500 nm by means of a mercury porosimeter Carlo Erba Strumentazione model 2000 (Fig. 2b). In the former case the determined air pore structure parameters were: total air content $(A)$, below-0.3 mm-diameter micropore content $(A_{300})$, air pore distribution index $(\bar{Z})$ and air pore specific surface area $(\alpha)$. In the latter case the following parameters were determined: total porosity $(p)$, specific pore volume $(V)$, average pore radius $(r)$ and specific pore area $(\alpha')$.
Fig. 1. Spread test results for: a) concrete mix A/SA (J-Ring); b) concrete mix D/SV (L-Box)

Fig. 2. Rigs for investigating air surface pores in hardened concrete by means of: a) image analyzer; b) mercury porosimeter

Fig. 3. Rig for measuring acoustic emission in compressed concrete: a) strength tester Instron 1126; b) measuring set Vallen-Systeme GmbH AMS3; c) concrete specimen prepared for testing
### Table 3. Averaged values of selected parameters characterizing pore structure of compared concretes A/S\textsubscript{A} and C/S\textsubscript{V} and B/S\textsubscript{A} and D/S\textsubscript{V}

<table>
<thead>
<tr>
<th>Investigated parameter</th>
<th>Concrete batch symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A/S\textsubscript{A}</td>
</tr>
<tr>
<td>Total air content in hardened concrete (A) [%]</td>
<td>6.70</td>
</tr>
<tr>
<td>Below-0.3 mm-diameter pore content (A_{300}) [%]</td>
<td>1.50</td>
</tr>
<tr>
<td>Air pore distribution index (L) [mm]</td>
<td>0.26</td>
</tr>
<tr>
<td>Specific air pore surface area (\alpha) [mm(^{-1})]</td>
<td>17</td>
</tr>
<tr>
<td>Total porosity (\rho) [%]</td>
<td>12.71</td>
</tr>
<tr>
<td>Specific pore volume (V) [mm(^3)/g]</td>
<td>24.08</td>
</tr>
<tr>
<td>Average pore radius (r) [nm]</td>
<td>3.90</td>
</tr>
<tr>
<td>Specific pore surface area (\alpha') [m(^2)/g]</td>
<td>7.12</td>
</tr>
</tbody>
</table>

3. Results of porosity structure investigations

The results of the porosity structure investigations for the hardened 90 day-old self-compacting concretes (A/S\textsubscript{A} and B/S\textsubscript{A} and C/S\textsubscript{V} and D/S\textsubscript{V}) are shown in Table 3. Diagrams illustrating the results are shown in Figs 4–6.

According to Table 3, total air content \(A\), below-0.3 mm-diameter pore content \(A_{300}\), total porosity \(\rho\), specific pore volume \(V\) and specific pore surface area \(\alpha\) in concrete C/S\textsubscript{V} modified with superplasticizer S\textsubscript{V} are substantially lower than in concrete A/S\textsubscript{A} modified with superplasticizer S\textsubscript{A}. Whereas pore distribution index \(L\), average pore radius \(r\) and specific air pore surface \(\alpha\) are higher for concrete C/S\textsubscript{V}. Therefore one can conclude that the polycarboxylic ether in superplasticizer S\textsubscript{A} causes considerable air entrainment in the self-compacting concrete. A similar conclusion emerges from the investigations carried out by the authors Gorzelańczyk and Hoła (2007), Khatib and Mangat (1999), Łażniewska-Piekarczyk (2009), Szwa-bowski and Łażniewska (2007).

![Fig. 4. Air pore content distribution depending on pore diameter in concretes: a) A/S\textsubscript{A} and C/S\textsubscript{V}; b) B/S\textsubscript{A} and D/S\textsubscript{V}](image)

![Fig. 5. Pore percentage for adopted radius intervals in pore radius range of 5–7500 nm for compared concretes: a) A/S\textsubscript{A} and C/S\textsubscript{V}; b) B/S\textsubscript{A} and D/S\textsubscript{V}](image)
According to Fig. 4a, the air content in concrete C/S\textsubscript{V} is lower almost in the whole test range of pore diameters. This is particularly visible in a pore diameter range of 180–1500 μm. A similar conclusion emerges from Fig. 6, with the difference that in the whole range of pore radii the porosity of concrete C/S\textsubscript{V} is lower than that of concrete A/S\textsubscript{A}. This means that the air pore structure in concrete C/S\textsubscript{V} modified with superplasticizer S\textsubscript{V} is characterized by better parameters than that of concrete A/S\textsubscript{A}. Similar conclusions regarding concretes B/S\textsubscript{A} and D/S\textsubscript{V} emerge from Table 3 and Fig. 4b, i.e. concrete D/S\textsubscript{V}, modified with superplasticizer S\textsubscript{V}, has better air pore structure parameters.

4. Failure investigation results and their analysis

The failure investigation results of the self-compacting concretes, obtained by the acoustic techniques, are compared for concretes A/S\textsubscript{A} and C/S\textsubscript{V} and concretes B/S\textsubscript{A} and D/S\textsubscript{V} in Figs 7–11.

Fig. 7 shows curves of longitudinal ultrasonic wave velocity versus relative compressive strength in concretes A/S\textsubscript{A} and C/S\textsubscript{V} (Fig. 7a) and in concretes B/S\textsubscript{A} and D/S\textsubscript{V} (Fig. 7b), with marked levels of initiating stress \(\sigma_i\) and critical stress \(\sigma_{cr}\), determined using the criteria given in Gorzelańczyk (2007, 2011) and Hola (2000b). As already mentioned, the levels demarcate the stages of failure of concrete under compression (Furtak 2002; Hola 1994, 2000a; Newman K., Newman J. B. 1971; Ngab et al. 1981) and are the visual effect of this process, observed during laboratory tests.

The results presented in Fig. 7 show that longitudinal ultrasonic wave velocity \(V_L\) in the concretes decreases as the compressive stress level increases. Similarly as in ordinary and high-performance concretes (Hola 2000a; K. Newman, J. B. Newman 1971), the velocity begins to fall at a certain stress level, falling ever faster when the latter is exceeded. The stress level is not the same in all the tested concretes. Velocity \(V_L\) begins to fall at 0.33 \(\sigma_c/f_c\) and 0.38 \(\sigma_c/f_c\) in respectively concrete A/S\textsubscript{A} and C/S\textsubscript{V}. The velocity of longitudinal ultrasonic waves in the concretes can be measured only up to a certain stress level since they are completely dampened when the latter is exceeded. The stress level is 0.90 \(\sigma_c/f_c\) and 0.93 \(\sigma_c/f_c\) in respectively concrete A/S\textsubscript{A} and C/S\textsubscript{V}. The levels are marked in Fig. 7a.
The investigations showed that the levels of cracking initiating stress $\sigma_i$ and critical stress $\sigma_{cr}$ are higher in concrete C/S$_V$, made using superplasticizer S$_V$, than in concrete A/S$_A$ made using superplasticizer S$_A$. The same was found for concretes B/S$_A$ and D/S$_V$, made using aggregate with the maximum grading of 8 mm (Fig. 7b).

Figs 8 and 9 show AE event rate $N_e$ over compression time for the compared concretes A/S$_A$ and C/S$_V$ and B/S$_A$ and D/S$_V$. The RMS AE signal over compression time for the concretes is shown in Figs 10 and 11. Figs 8–11 include a plot of relative compressive stress $\sigma/f_c$ versus failure time $t$, and levels of $\sigma_i$ and $\sigma_{cr}$ determined according to the criteria given in Gorzeląńczyk (2007) and Hola (2000b).

![Fig. 8. AE event rate $N_{ez}$ referred to relative compressive stress $\sigma_c/f_c$ versus failure time for self-compacting concrete: a) A/S$_A$; b) C/S$_V$](image1)

![Fig. 9. AE event rate $N_{zd}$ referred to relative compressive stress $\sigma_c/f_c$ versus failure time for self-compacting concrete: a) B/S$_A$; b) D/S$_V$](image2)

![Fig. 10. RMS AE signal, referred to relative compressive stress $\sigma_c/f_c$ versus failure time for self-compacting concrete: a) A/S$_A$; b) C/S$_V$](image3)
According to Figs 8–11, the diagrams of event rate $N_{ev}$ and the RMS AE signal versus failure time are similar for all the tested concretes: initially the values of the two recorded descriptors are small, then event rate $N_{ev}$ and the RMS signal moderately increase and in the final stage of failure they sharply increase.

The results presented in Figs 7–11 clearly show that the failure of the ordinary and high-performance concretes proceeds in three stages.

The levels of cracking initiating stress $\sigma$ and critical stress $\sigma_{cr}$, in the compared concretes A/S$_A$ and C/S$_V$ and B/S$_A$ and D/S$_V$, determined in Figs 7–11, are compiled in Table 4. The table also includes (relative and absolute) average values of stresses $\sigma_{im}$ and $\sigma_{cr}$ calculated using the results obtained by means of the two investigative techniques.

It appears from Table 4 that in comparison with concrete A/S$_A$, concrete C/S$_V$ is characterized by a considerably higher level of cracking initiating stress $\sigma_{im}$ and a slightly higher level of critical stress $\sigma_{cr}$. The same applies to concrete D/S$_V$ in comparison with concrete B/S$_A$. It should be noted that concretes C/S$_V$ and D/S$_V$ were made using superplasticizer S$_V$.

It should be noted here that as the literature survey (Gorzelańczyk 2007; Hoła 2002) indicates, cracking initiating stress in ordinary and high-strength concretes generally occurs at a relatively higher relative compressive stress $\sigma_{f_c}$ than in the self-compacting concretes tested here. This is due to, among other things, the composition of the self-compacting concretes: the latter contain much more fine-grain aggregate fractions and dusty additives than ordinary and high-strength concretes (Hola 1992).

In order to illustrate the influence of air pore structure on the failure of the self-compacting concretes, diagrams of the dependence of the average relative levels of cracking initiating stress $\sigma_{im}$ and critical stress $\sigma_{cr}$ on such air pore structure parameters as: total air content $A$ (Fig. 12), total porosity $p$ (Fig. 13), air pore distribution index $\alpha$ (Fig. 14) and specific air pore surface area $\alpha$ (Fig. 15) were drawn.

It follows from Figs 12 and 13 that in the compared concretes A/S$_A$ and C/S$_V$ and B/S$_A$ and D/S$_V$ lower air content $A$ and lower total porosity $p$ are connected with higher levels of cracking initiating stress $\sigma_{im}$ and critical stress $\sigma_{cr}$. The explanation can be that the lower the air content in the hardened concrete and the lower the total porosity, the smaller the number of places in which the structure is weakened. This is reflected in the fact that the stage of stable development of microcracks begins at a higher strain during the failure of the concrete.

Figs 14 and 15 show that higher pore distribution index $\alpha$ and larger specific air pore surface area $\alpha$ are connected with higher values of stress $\sigma_{im}$ and stress $\sigma_{cr}$. Therefore one can conclude that when air pores are

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**Table 4.** Levels of stress $\sigma$ and $\sigma_{cr}$ and (relative and absolute) average values of $\sigma_{im}$ and $\sigma_{cr}$ stress levels in concretes A/S$_A$, C/S$_V$, B/S$_A$ and D/S$_V$, determined by ultrasonic technique and AE technique

<table>
<thead>
<tr>
<th>Concrete batch symbol</th>
<th>Measuring technique</th>
<th>Average values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>$\sigma_{im}$ MPa</td>
</tr>
<tr>
<td>A/S$_A$</td>
<td>$\sigma_1$ [-] 0.33</td>
<td>0.33 [-] 0.33</td>
</tr>
<tr>
<td></td>
<td>$\sigma_2$ [-] 8.7%</td>
<td>5.4% [-] 0.91</td>
</tr>
<tr>
<td>B/S$_A$</td>
<td>$\sigma_1$ [-] 0.31</td>
<td>0.30 [-] 0.30</td>
</tr>
<tr>
<td></td>
<td>$\sigma_2$ [-] 7.6%</td>
<td>8.6% [-] 0.86</td>
</tr>
<tr>
<td>C/S$_V$</td>
<td>$\sigma_1$ [-] 0.38</td>
<td>0.38 [-] 0.38</td>
</tr>
<tr>
<td></td>
<td>$\sigma_2$ [-] 6.4%</td>
<td>6.6% [-] 0.92</td>
</tr>
<tr>
<td>D/S$_V$</td>
<td>$\sigma_1$ [-] 0.33</td>
<td>0.34 [-] 0.34</td>
</tr>
<tr>
<td></td>
<td>$\sigma_2$ [-] 8.8%</td>
<td>5.9% [-] 0.90</td>
</tr>
</tbody>
</table>

Note: the variation coefficient value is given under the bar.
Fig. 12. Dependence of average relative levels of stress $\sigma_{im}$ and $\sigma_{crm}$ on total air content $A$ in hardened self-compacting concrete (pore diameter range 10–4000 μm): a) A/S\textsubscript{A} and C/S\textsubscript{V}; b) B/S\textsubscript{A} and D/S\textsubscript{V}.

Fig. 13. Dependence of average relative levels of stress $\sigma_{im}$ and $\sigma_{crm}$ on total porosity $p$ in hardened self-compacting concrete (pore radius range 5–7500 nm): a) A/S\textsubscript{A} and C/S\textsubscript{V}; b) B/S\textsubscript{A} and D/S\textsubscript{V}.

Fig. 14. Dependence of average relative levels of stress $\sigma_{im}$ and $\sigma_{crm}$ on air pore distribution index $L$ in hardened self-compacting concrete (pore diameter range 10–4000 μm): a) A/S\textsubscript{A} and C/S\textsubscript{V}; b) B/S\textsubscript{A} and D/S\textsubscript{V}.

Fig. 15. Dependence of average relative levels of stress $\sigma_{im}$ and $\sigma_{crm}$ on specific air pore surface area $\alpha$ in hardened self-compacting concrete (pore diameter range 10–4000 μm): a) A/S\textsubscript{A} and C/S\textsubscript{V}; b) B/S\textsubscript{A} and D/S\textsubscript{V}.
distributed more sparsely and their specific surface area is larger, then the structure is more homogenous. In such concrete the stage of stable propagation of cracks begins at a higher stress level and the stage of catastrophic failure is slightly shorter.

5. Using stress levels to calculate fatigue strength of concretes

The experimentally determined cracking initiating stress \( \sigma_i \) and critical stress \( \sigma_{cr} \) were used to calculate the fatigue strength of the concretes under compression from relation (1) given by Furtak (1997):

\[
f_{f} / f_{c} = CN^{-A} \left( 1 + B \rho f \log N \right) C_f,
\]

where: \( C \) – a coefficient expressing the ratio of dynamic strength to static strength under one-time loading (as in Furtak (1997)), the coefficient was assumed to be equal to 1.16; \( \rho_f \) – a stress ratio; \( \sigma_{c,\text{min}} \) – the minimum cycle stress; \( \sigma_{c,\text{max}} \) – the maximum cycle stress; \( C_f \) – a coefficient expressing the influence of load change rate on fatigue strength; \( A \), \( B \) – coefficients representing the condition of concrete structure by being dependent on stress \( \sigma_i \) and \( \sigma_{cr} \).

According to Furtak (1997), stress ratio \( \rho_f \) is described by the relation:

\[
\rho_f = \frac{\sigma_{c,\text{min}}}{\sigma_{c,\text{max}}},
\]

and coefficient \( C_f \) can be described by the relation:

\[
C_f = 1 + 0.07 \left( 1 - \rho_f \right) \log f,
\]

where \( f \) is a load change rate [Hz] and coefficients \( A \) and \( B \) can be calculated from relations (4) and (5):

\[
A = 0.008 - 0.118 \log(\sigma_i / f_{c}),
\]

\[
B = 0.118 (\sigma_{cr} / \sigma_i - 1).
\]

It appears from the Fig. 16 that concretes C/S\(_V\) and D/S\(_V\) modified with superplasticizer S\(_V\) have higher fatigue strength than concretes A/S\(_A\) and B/S\(_A\) modified with superplasticizer S\(_A\).

6. Conclusions

1. There are significant differences in air pore structure between the four hardened self-compacting concretes made from the mixes characterized by similar rheological properties. The structure depends on the superplasticizer used in the making of the concrete mix. When superplasticizer S\(_V\) (based on a combination of polycarboxylates and viscosity, setting and hardening regulators) is added, the obtained structure is characterized by more advantageous parameters than the structure of the concrete made using superplasticizer S\(_A\) (based on polycarboxylic ether).

The more advantageous parameters are:
- lower total air content \( A \);
- lower below-0.3 mm-diameter micropore content \( A_{300} \);
- lower total porosity \( p \);
- smaller specific pore volume \( V \);
- smaller specific pore area \( \alpha \);
- higher pore distribution index \( T \);
- larger specific pore surface area \( \alpha \);
- larger average pore radius \( T \).

2. The investigations of the failure of the self-compacting concretes by means of the acoustic techniques (the ultrasonic technique and the acoustic emission technique) showed that air pore structure has an influence on the course of this process. The concretes made with the addition of superplasticizer S\(_V\) are characterized by higher levels of cracking initiating stress \( \sigma_i \) and critical stress \( \sigma_{cr} \), in comparison with the concretes made with the addition of superplasticizer S\(_A\).

3. There are considerable differences in the fatigue strength calculated using the determined average levels of crack initiating stress \( \sigma_{im} \) and critical stress \( \sigma_{crm} \) between the self-compacting concretes. The concretes made with the addition of superplasticizer S\(_V\) have higher strength than the concretes made with the addition of superplasticizer S\(_A\). Therefore it can be stated that concrete mixes modified with superplasticizer S\(_V\) are more suitable for making structures which are subject to cyclic loads.

References


T. Gorzelańczyk. Acoustically assessed influence of air pore structure on failure of self-compacting concretes...

Santrauka


Reikšminiai žodžiai: susitankinantis betonas, porų struktūra, susilpnėjimas, gniuždymas, akustinė emisija, ultragarsai.

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