CONCRETE, HARDENED:
AIR VOID STRUCTURE AND AIR CONTENT

1. SCOPE AND APPLICATION

The method can be applied to determine the air content and air-void structure in hardened concrete. The air-void structure is described by means of the parameters, specific surface, spacing factor and air-void distribution.

The method can be applied to test the air-entraining agents, and also to assess the quality of the air-void structure in the hardened concrete.

This standard is suitable for manual, semi-automatic and fully automatic measurements.

2. REFERENCES

NT BUILD 191 Betongprovning - Färs betong - Provtagning
NT BUILD 202 Betong provning - Hårdnad betong - Utborrning och behandling av cylindrar för hållfasthetsbestämning.
3. SAMPLING

If no sampling procedure is described in the test report, the sampling is as stated in NT BUILD 191 or 202.

4. MEASURING SYSTEM

4.1 Principle

The measuring is carried out by registering the number and length of chords greater than 8 µm, within air-voids along a test line. The total length of chords related to the total test line determine the volume of air in the sample.

The content of aggregates is determined in the same way as the air content. The designed content of aggregates in the mix can be used instead of the measurements. But the report must state whether the designed or the measured content of aggregates is used.

If the air content and the content of aggregates are known, the cement paste content can be calculated.

When the composition of the concrete is determined, it is possible to calculate the specific surface, the spacing factor and the air-void distribution by means of the above mentioned parameters.

4.2 Equipment

Concrete saw
Grinding machine, with a cast iron disc having a minimum diameter of 400 mm
Silicone carbide powder, grain size approximately 120, 60, 30, 16 and 12 µm
Glycerol
Nail hardener
Acetone
Stamp ink, black, dull, not water-soluble
Zinc paste
Gypsum powder, grain size \( \leq 3 \, \mu m \)

Steel scraper

Refrigerator

Oven

Microscope, resolution \( \leq 2 \, \mu m \)

Linear traverse device with an accuracy in length determination of about 3 \( \mu m \).

4.3 Preparation

The samples may be cast in the laboratory or be drilled cores from the site. A slice is cut from the sample having a surface area as stated in Table 1. The slice must be carefully marked. The test area should be placed at least 5 mm from sawing- and drilling edges.

It may be necessary to use more than one sample for one measurement to obtain the test areas stated in Table 1.

<table>
<thead>
<tr>
<th>Aggregate Size</th>
<th>Min. total Surface area</th>
<th>Semi-automatic measurement line length</th>
<th>Automatic measurement test area</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm(^2)</td>
<td>mm</td>
<td>mm(^2)</td>
</tr>
<tr>
<td>64</td>
<td>35.000</td>
<td>2.800</td>
<td>3.500</td>
</tr>
<tr>
<td>32</td>
<td>12.000</td>
<td>2.500</td>
<td>1.200</td>
</tr>
<tr>
<td>16</td>
<td>7.000</td>
<td>2.200</td>
<td>700</td>
</tr>
<tr>
<td>8</td>
<td>5.500</td>
<td>1.800</td>
<td>500</td>
</tr>
</tbody>
</table>

Table 1. Minimum total test areas and test line lengths by different aggregate sizes. Linear interpolation is used for intervening aggregate sizes.

The section of the sample is ground for about 5 minutes on the grinding machine under continuous adding of abrasives mixed in glycerol and water. The sample and the grinding wheel are then cleaned by using a brush and washed under running water. After washing the sample is rotated 90° counter-clockwise.
The grinding is made with each powder grade to produce a plane surface of good quality.

The grinding powder of grain size 16 µm may be omitted when the cement paste is strong. Before each change of powder grade, the surface should be checked for defects and wear of the cement paste. The surface may be considered satisfactory when the edges of the air-voids are sharp and well-defined.

The surface should be without scratches. Air-voids are seen as round shaped cavities. Missing grains (torn out during grinding) show cavities with sharp, irregular edges.

If the cement paste is weak, it may be strengthened in two different ways:
1. Storage in hot water up to 80 ºC.
2. Nail hardener is applied to the surface before the final stage of grinding. The nail hardener must be removed completely with acetone before measuring.

The sample can be treated with a special preparation to produce a better contrast between the air-voids and the cement paste. (This is necessary when the automatic measurements are to be taken). This is done by applying ink to the surface from a stamp pad or roller. Care must be taken to prevent the ink from sinking into the air-voids. The sample is then placed in the oven at 50 ºC for 4 hours. It is then covered with zinc paste and the excess zinc paste is removed after refrigeration. Finally, the surface is covered with gypsum powder which is pressed into the zinc-paste filled air-voids. The excess gypsum powder is removed with a scraper.

### 4.4 Procedure

The test area or the test lines are distributed evenly over the prepared surface making a minimum area or length as stated in Table 1.
The sample is mounted on the stage of the microscope. During measurements the following parameters are registered:

- total length of test line, \( l_{\text{tot}} \)
- length of each chord within air-voids
- total length of chords within air-voids, \( l_i \)
- total number of chords within air-voids, \( N_i \)
- perhaps the total length of test lines greater than 30 \( \mu m \) within aggregates, \( l_t \)

The total length of chords within air-voids greater than 8 \( \mu m \) and smaller than 1.5 mm is calculated \((l_i)\). The total air content \((V_1)\) is calculated:

\[
V_1 = \frac{l_i}{l_{\text{tot}}} \times 100 \quad \%\]

The content of aggregates \((V_t)\) is determined from proportioned quantities or as:

\[
V_t = \frac{l_t}{l_{\text{tot}}} \times 100 \quad \%
\]

The cement paste content is calculated:

\[
V_{cp} = 100 - (V_1 + V_t) \quad \%
\]

The air-void distribution is determined by registering the number of air-voids, respectively the volume of air-voids per unit volume of concrete in different size classes from:

\[
n_{d,j} = \frac{2}{\pi} \cdot \left( \frac{n_{a,j}}{a_j} - \frac{n_{a,j+1}}{a_{j+1}} \right)
\]

where,

- \( n_{d,j} \) = number of air-voids per volume unit in size class \( d_j \), \( d_{j+1} \)
- \( n_{a,j} \) = number of chords within air-voids per length unit in size class \( d_j \), \( d_{j+1} \)
\[ \Delta_j = d_{j+1} - d_j \]

\[ a_j = \frac{(d_j + d_{j+1})}{2} \]

\[ V_{1,j} = \frac{\pi}{6} \cdot n_{d,j} \cdot a_j^3 \]

where

\[ V_{1,j} = \text{volume of air-voids with diameter in size class } d_j, d_{j+1} \]

4.5 Results

The air content \( (V_1) \) is stated as \( \frac{V_1}{V_{1\text{tot}}} \cdot 100 \% \) as mentioned above.

The specific surface of the air-void system, the surface of the air-voids related to their volumes is stated as:

\[ S_V = \frac{4 \cdot N_1}{l_1} \]

The spacing factor is stated as:

\[ \bar{L} = \frac{3}{S_V} \cdot \left[ 1.4 \cdot \left( \frac{V_{cp}}{V_1} + 1 \right)^{1/3} - 1 \right] \text{ for } \frac{V_{cp}}{V_1} \geq 4.33 \]

\[ \bar{L} = \frac{V_{cp} \cdot l_{tot}}{400 \cdot N_1} \text{ for } \frac{V_{cp}}{V_1} < 4.33 \]

The air-void distribution is stated as a curve showing the accumulated volume part of air-voids, up to a certain diameter as a function of the diameter of the air-voids.

The accumulated volume part of air-voids with a diameter less than \( d_{j+1} \) is calculated from
\[ \sum_{k=1}^{n_{\text{int}}} V_{1,k} = V_1 \]

where

\[ \sum_{k=1}^{n_{\text{int}}} V_{1,k} \]

\[ v_1 = \text{total volume of air-voids} \]

4.6 **Test report**

The test report shall include the following information, if relevant:

a) Name and address of the testing laboratory
b) Identification number of the test report
c) Name and address of the organization or the person who ordered the test
d) Purpose of the test
e) Method of sampling and other circumstances (date and person responsible for the sampling)
f) Name and address of manufacturer or supplier of the tested object
g) Name or other identification marks of the tested object
h) Description of the tested object
i) Date of supply of the tested object
j) Date of the test
k) Test method
l) Conditioning of the test specimens, environmental data during the test (temperature, pressure, RH, etc)
m) Identification of the test equipment and instruments used
n) Any deviations from the test method
o) Test results (use SI units)
p) Inaccuracy or uncertainty of the test result

Date and signature