CONCRETE, FRESH:
COMPACTIBILITY WITH IC-TESTER
(INTENSIVE COMPACTION TESTER)

Key words: Concrete, fresh concrete, compactability, IC-tester

1. SCOPE

The IC-tester compacts the mass sample (ca. 0.8 dm$^3$) using a continuous, kneading action. Pressure and cyclic shearing is applied to the mass. At the end of the test an ICT-index is obtained which describes the amount of work needed to compact the sample to a specified density. The compaction takes place in a test cylinder with oscillating end plates in such a way that the concrete mass is subjected to cyclic shearing. The concrete cylinder which is obtained after the compaction may be subjected to compressive or splitting strength tests at different ages.

This method can be employed in quality control of concrete as well as in research and product development.

2. FIELD OF APPLICATION

This test method is applicable to fresh concrete with a slump less than ca. 2 cm and VB-times longer than ca. 5 sec. The maximum particle size of aggregate is 20% of the diameter of the working cylinder.

Stiff concrete masses are used in the manufacture of concrete elements, pavements, roofing tiles, pipes and in road building. The masses are compacted by means of pressure and vibration, extrusion or rolling.

3. REFERENCES

ISO 4012 Concrete - Determination of compressive strength of test specimens. 1978.

ISO 4108 Concrete - Determination of splitting strength of test specimens. 1980.

ISO 1920 Concrete tests - Dimensions, tolerances and applicability of test specimens. 1976.


4. DEFINITIONS

In this test the ICT-cycle (working cycle) is specified as one revolution of the eccentric axis of the apparatus. In the course of the cycle a continuous alteration of the angle between the wall of the cylinder and the end plates can be seen, and towards the end of the cycle the original value of the angle is restored.

Slurry is defined as a suspension (of binding matter, the finest fraction of the aggregate, water and possible admixtures) which may be extruded from the sample at the end of the test.

Slurry limit is defined as the number of ICT-cycles needed for separation of slurry from the sample. The slurry limit has been reached when the first drop of slurry is seen to penetrate through the lower part of the working cylinder (visual observation). When the slurry limit is exceeded, compaction is considered to be adequate.

The time after addition of water is defined as the time elapsed from the addition of mixing water to the dry constituents of the concrete mass.

Amplitude is defined as the maximum difference from perpendicular between the wall of the cylinder and the end plate.

The ICT-index is defined as the pressure multiplied by the number of ICT-cycles (the formula is presented in Chapter 6.7).

The fresh strength is defined as the splitting strength determined immediately after running the ICT-test but is determined using a procedure different from that for the splitting strength at older ages. It is not necessary to determine an accurate strength value of the fresh concrete. Instead, an approximate value (in kPa) is obtained, which describes the splitting strength without delay after the preparation of the specimen.

5. SAMPLING

Samples are taken from the mixer or from another relevant site. Three parallel samples are taken from the concrete mix for
testing. Samples should be taken from well-mixed and homogeneous materials. The samples are tested 5, 10 and 15 min after addition of water. Tests for the compressive and splitting strength or tests for the strength at various ages require parallel samples to be tested also 20, 25 and 30 min after the addition of water. Additionally, samples can be taken from another similar concrete mass (parallel mass). During the handling of the specimens care must be taken to cut down the evaporation of water as much as possible (the mass ought to be covered with a plastic sheet and protected from sunlight). Should the mass be subjected to tests after a specific time interval e.g. at the point of casting, three parallel samples should to be taken within 15 min.

6. METHOD OF TEST

6.1 Principle

The apparatus compacts the fresh concrete mass using the method of Intensive Compacting, which means that the mass is compacted slowly and mechanically using precise, continuous working action. The concrete sample is compressed in a work cylinder equipped with end plates that are parallel to each other but not perpendicular to the cylinder wall. With the aid of an eccentric device the end plates are brought into a slowly oscillating movement in such a way that the angle between the plates and the cylinder wall is altered continuously. In concurrency with this movement the pressure affects the end plates. In other words, the concrete mass inside the cylinder is concurrently subjected to pressure and cyclic shearing.

During the compaction the apparatus continuously measures the height of the concrete cylinder and on the basis of the height and the weight of the sample, the density of the sample is calculated as a function of the number of ICT-cycles.

6.2 Apparatus

The ICT-measurement is made by an apparatus which in this method should be of the standard design ICT-100, i.e. any of the models R-81, 100S, 100R or 100RB. The work cylinder should be made of hardened steel. The following parameters characterise the apparatus:

- The diameter of the work cylinder: 100 mm
- The difference between the inside diameter of the work cylinder and the diameter of the end plates: 0.3-0.5 mm
- Amplitude: 4 mm/l 00 mm (2°17”) ± 2 % adjustable in some models
- Working speed: 40-120 ICT-cycles/min
- Maximum consolidation pressure in the work cylinder: 320 kPa, corresponding to 8 bar in the pneumatic cylinder of the apparatus

A detailed description of the apparatus can be found in the operation handbook.

6.3 Calibration of the apparatus

The sample volume can be calculated from measurements of the upper piston position. The position measuring device shall be calibrated before each series of measurements. The calibration is performed with the aid of a steel measurement tool according to the directions for use of the apparatus.

6.4 The ICT-procedure

The pressure is adjusted to 4 bars in the pressure cylinder of the apparatus (corresponding to the compressive pressure 160 kPa in the working cylinder during the test). The working speed is adjusted to 60 rpm (a faster of 120 rpm may alternatively be used for special purposes). The amplitude shall be adjusted to 4 mm / 400 mm (2°17”) ± 2 % (the mode of action is described in the directions for use). These working parameters are kept unchanged throughout the whole test.

First a certain quantity of concrete mass is weighed in the working cylinder (parallel sample 1). The quantity is selected (it might be determined on the basis of the proposed density) in such a way that the height of the concrete cylinder is 100-110 mm after the termination of the test. The specimen volume is then ca. 0.78-0.86 dm³ (ordinary concrete masses demand ca. 1900-2100 g). When the working cylinder is filled the separation of fresh concrete must be avoided, and the cylinder is filled with a representative sample. The cylinder is fastened into the apparatus. The apparatus is started 5 min after the addition of water and the test is carried out in accordance with instructions.

The apparatus may be stopped automatically or manually

- At a specified number of cycles
- At a specified density
- At the slurry limit

After the operation the concrete specimen is pushed out from the work cylinder, weighed and sealed in a plastic bag.

Immediately after the first test, the procedure is repeated (parallel sample 2), and the apparatus is started 10 min after the addition of water. Parallel sample 3 is tested 15 min after the addition of water.

Slurry limit is estimated on the basis of visual observation and weighing. After the slurry limit has been passed, the measurement is repeated making use of fewer ICT-cycles (e.g. 10 % fewer cycles). If the slurry limit is not found in the range 25-128 ICT-cycles, the test is repeated with a modified pressure as found in Table 1.
Table 1. Suggested limits for the slurry limit at various pressures.

<table>
<thead>
<tr>
<th>Pressure (bar)</th>
<th>Slurry limit (ICT-cycles)</th>
<th>Slurry limit (ICT-index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>6-25</td>
<td>3-12</td>
</tr>
<tr>
<td>1</td>
<td>8-40</td>
<td>8-40</td>
</tr>
<tr>
<td>2</td>
<td>12-80</td>
<td>24-160</td>
</tr>
<tr>
<td>4</td>
<td>25-128</td>
<td>100-512</td>
</tr>
<tr>
<td>6.3</td>
<td>64-</td>
<td>403-</td>
</tr>
</tbody>
</table>

6.5 Preparation of specimens for determination of strength

After the specimen has been removed from the work cylinder it is stored during the first day in a plastic bag at RH > 95 % and 20 ± 2 °C. The compressive strength may be determined using two alternative ways. The specimen is prepared as follows:

Alternative I (ISO - strength)

Before the determination of the compressive strength the end sections of the specimens are straightened and smoothed according to ISO 4012. The height of the cylinders should be 100 ± 5 mm after straightening and smoothing. Form tolerances should comply with the specifications in ISO 4012.

Alternative II (ICT - strength)

The end sections are not straightened. The slant should be not more than 4.4 mm/100 mm and the smoothness 0.5 mm.

6.6 Determination of strength

The fresh strength is determined immediately after the ICT-test by compressing the horizontally positioned specimen between two parallel surfaces and using scales. The breaking load (max. load) is registered. The calculated fresh splitting strength is an estimation of the fresh strength of the specimen. The fresh strength is calculated according to the following formula:

\[ f_s = \frac{6.24 \times 10^3 \cdot F}{d \cdot h} \]

where

- \( f_s \) is fresh strength (kPa)
- \( F \) max load (kg)
- \( d \) diameter of the specimen (mm)
- \( h \) height of the specimen (mm)

The splitting strength is determined according to ISO 4108 except the form tolerances which comply with the specifications in Section 6.5.

The compressive strength may be tested using the following two alternative ways:

Alternative I (ISO - strength)

The strength is determined according to ISO 4012

Alternative II (ICT - strength)

The strength is determined according to ISO 4012 with the following exceptions: The form tolerances comply with the specification in Section 6.5. Should the end surfaces not be smoothed out, then 10 mm thick porous fibre plates are positioned between the end surfaces of the test cylinder and the compressing plates.

6.7 Expression of results

Depending on which alternative was chosen in the procedure, the results are presented in the following way:

- a) Compactability is expressed as an ICT-index at the slurry limit and it is calculated according to the following formula:
  \[ I = n \cdot P \]
  where
  - \( I \) is ICT-index (without dimensions)
  - \( P \) pressure/bar in the pneumatic cylinder of the apparatus (manometer reading)*
  - \( n \) number of ICT-cycles

- b) Slurry limit (number of ICT-cycles)

- c) Pressure (bar) in the pressure cylinder of the apparatus during the test

- d) Quantity of slurry, which is calculated according to the formula:
  \[ S = m_1 - m_2 \]
  where
  - \( S \) is weight of slurry (g)
  - \( m_1 \) weight of concrete in the work cylinder at the beginning of the test (g)
  - \( m_2 \) weight of the concrete specimen after the test

- e) Density of the concrete specimen (kg/dm³) at the slurry limit**

- f) Density of the concrete sample (kg/dm³) at 10, 20, 40, 80 and 160 ICT-cycles

- g) Final density of the concrete sample (kg/dm³)

* The apparatus supplies the pressure reading in bars, thus it is in practice convenient to use bar in the calculations of the ICT-index instead of the SI-unit MPa.

** The corrected value taking into account the slurry loss
h) The number of ICT-cycles needed for a specified density
i) An estimation (kPa) of the fresh strength
j) The strength (MPa) and test age and the alternative which has been used to estimate the strength
k) The dimensions of the specimens before and after straightening and smoothing
l) The number of concrete mixes and the number of samples/mix

Results are given as single data values, mean values and standard deviation of three determinations.

6.8 Precision

The precision of the density provided by the IC-tester at a specific ICT-index is dependent on nearness to the theoretical maximum density. The correlation for concrete with density 2490-2510 kg/m³ is presented in Table 2.

Table 2. The correlation between precision and density.

<table>
<thead>
<tr>
<th>Relative density (Oh of theor. max.)</th>
<th>Repeatability</th>
<th>Reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>93 %</td>
<td>1.2 %</td>
<td>1.9 %</td>
</tr>
<tr>
<td>96 %</td>
<td>1.2 %</td>
<td>1.8 %</td>
</tr>
<tr>
<td>98 %</td>
<td>1.0 %</td>
<td>1.6 %</td>
</tr>
<tr>
<td>100%</td>
<td>0.6%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

The precision of the number of cycles of a specific density and therefore also the ICT-index is closely related to the nearness to the theoretical maximum density. The larger the density, the smaller the precision. When density is 98 % of the theoretical maximum density, precision is as follows:

Repeatability 30 %
Reproducibility 40 %

6.9 Report

The report should contain the following information:

a) The name and address of the laboratory
b) The identification number of the report
c) The name and address of the organisation or person who ordered the test
d) The aim of the test
e) The sampling method and other conditions (date and the name of the person who is responsible of the sampling)
f) The name and address of the manufacturer or supplier of the tested concrete mass
g) The identification label of the tested concrete mass
h) Description of the tested concrete mass
i) The temperature of the concrete mass
j) The age of the concrete mass at the end of the IC-test (the time after addition of water)
k) Test date
l) Test method
m) Conditions during the test (temperature, pressure, RH, etc.)
n) Identification of the test apparatus
o) Deviations from the test method
p) Handling of the end surfaces of the concrete specimens
q) Mixing time of the concrete mass
r) Results (SI-units)
s) Uncertainties and inaccuracy of the results
t) Date and signature