Influence of Surface Preparation Method on the Concrete Rebound Number obtained from Impact Hammer Test

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Abstract
For concrete strength detection in structures different testing procedures are being used. For nondestructive testing of concrete strength built in the construction the most used impact hammers in technical practice are those of Schmidt system. The hammer rebound value on concrete is influenced by number of factors, these includes the treatment of the test area. In the article there are presented testing results of concrete by rebound hammer type Schmidt N and L made on the test surface treated by two different ways (according to CSN 73 1373 and EN 12504-2). Hardness test methods are indirect methods of determining the strength of concrete, i.e. compressive strength of concrete is determined from the calibration relationship between parameter of non-destructive testing and strength of concrete. The basic factors affecting the hammer rebound value are: test area treatment, concrete composition, concrete humidity, hammer position, age of concrete, carbonation. Test area preparation according to EN 12504-2 Using the abrasive stone, grind heavily textured or soft surfaces, or surfaces with loose mortar, until they are smooth. Smooth-formed or trowelled surfaces may be tested without grinding. Remove any water present on the surface of the concrete. Areas exhibiting honeycombing, scaling, rough texture, or high porosity should be avoided. Test area preparation according to CSN 73 1373 - the test area is cleared of carbonated concrete layers and is dry grinded so that the concrete structure is visible. There was demonstrated single valued effect of the test area treatment method on hammer rebound values. Test surface preparation according to EN 12504-2 is simpler though, but for this type of testing is not optimal.

Keywords: non-destructive testing; rebound hammer; test area; preparation; concrete

1. Introduction

For estimation of compressive strength of concrete in structures are using different testing procedures. Compressive strength of concrete can be found as follows: destructive by taking core bore samples from a structure; non-destructive by Schmidt rebound hammer or ultrasonic pulse velocity method; semi-destructive test methods or a combination of destructive and non-destructive testing. Standard procedures have been established and are described in detail in European and national standards. The rebound hammer was determined as indicated by the European standards: CSN EN 12504-2[2], Czech technical standard: CSN 731373[3] and standards as ASTM C 805-97[4], JGJ/T 23-2001[5]. System of Schmidt impact hammers is the most used in practice. It is using word-wide as an index of test for estimate strength of concrete, due to it is rapidity, portability, easiness in execution, and beside this low cost. The results of Schmidt rebound hammer are influenced by large numbers of factors. The basic one is preparation of test surface. In this paper are presented results of concrete by rebound hammer type Schmidt N and L. Preparation of test area has been carried out two different ways, according to CSN 73 1373 [3] and CSN EN 12504-2[2].

2. Basic characteristics of impact hammers

The most popular impact hammers currently used for concrete testing is Schmidt system by producer Proceq SA Switzerland in 2 basic types, varying each other of impact energy. Type N impact energy- 2.207Nm; type L impact energy - 0.735Nm.
Nowadays, the manufacture program of Schmidt impact hammer system includes two variants: 1) “Original” impact hammer, the resulting value of which is the rebound number; and 2) “Silver” impact hammer as a new type, which is an integrated electronic hammer with test resulting value of $Q$ rebound coefficient gained from impact and rebound velocity, both detected before and immediately after the impact and computing the fraction of energy restored by the specimen under the test. Nevertheless, the building industry uses impact hammers, type N, most frequently, made by various manufactures and delivered under different commercial marks, such as OShB-1, Elcometer etc., all having technical parameters, similar to those of the Schmidt system.

3. Influence affecting hammer rebound number

Hardness test methods are indirect methods of determining the strength of concrete, i.e. compressive strength of concrete is determined from the calibration relationship between parameter of non-destructive testing and strength of concrete. The basic factors affecting the hammer rebound value are:

- Test area treatment
- Concrete composition— it affects the hammer rebound value – affects the usage of basic calibration relationship for concrete strength determining
- Concrete humidity — hammer rebound value of concrete with various content of moisture is different, this is reflected e.g. in CSN 731373[3] with humidity correction factor $\alpha_w$, which varies from 0.85–1.05 (dry concrete with humidity to 0.5 % – water saturated concrete);
- Hammer position (the effect of Earth's gravity, gravity effect at spring hammers) – is normally reflected in the tables for determining of concrete strength (for the same rebound value depending on the location of hammer is indicated various compressive strength of concrete);
- Age of concrete - this is reflected e.g. in the CSN 731373[3] with concrete age correction factor $\alpha_t$, which ranges from 0.95 to 0.90. The correction value $\alpha_t$, which is 0.9 for concretes older than one year, it doesn’t correspond to reality. For concrete in age 10 to 30 years generally varies from 0.5 to 0.65. Changes to the hardness of the surface layer of concrete are different with increasing age due to physico-chemical processes in the hardened cement mortar, and it is also affected relation to hardness - strength of concrete. Most often it is a process of carbonation. Therefore, for testing is required before starting to remove loose mortar and heavily textured of concrete by grounding.
- Carbonation depth of the concrete surface – the concrete surface carbonation depth significantly affects the rebound hammer value; In the chinese JGJ/T 23-2001[5] standard there are listed compressive strength table values for the given rebound value, which reflects concrete carbonation depth (0-6 mm).

2.1 Test area preparation according to CSN EN 12504-2[2]

Using the abrasive stone, grind heavily textured or soft surfaces or surfaces with loose mortar, until they are smooth. Smooth-formed or trowel led surfaces may be tested without grinding. Remove any water present on the surface of the concrete. Areas exhibiting honeycombing, scaling, rough texture, or high porosity should be avoided.
2.2 Test area preparation according to CSN 73 1373[3]

The test area is cleared of carbonated concrete layers and is dry grinded so that the concrete structure is visible. Concrete with cube strength above 40 MPa may be tested on non-ground surface too, if it has been demonstrated in a comparative test on grinded and non-ground place that the rebound values are practically the same.

2.3 Concrete used for testing

The experimental program has been carried out on the concretes class C25/30 and C30/37. The concrete has been stored in two different conditions. Composition of concrete is shown in table 1.

- Standard storage (t = 20 ± 2°C, φ ≥ 95%),
- “Dry” storage (t = 20 - 23°C, φ = 30 - 35 %).

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>C25/30</th>
<th>C30/37</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Mill - CEM II/A-S 32,5 R</td>
<td>381</td>
<td>405</td>
</tr>
<tr>
<td>Ledče: fine aggregate 0/4</td>
<td>778</td>
<td>800</td>
</tr>
<tr>
<td>Olbramovice: Coarse aggregate 8/16</td>
<td>664</td>
<td>633</td>
</tr>
<tr>
<td>Lomnička Coarse aggregate 011/22</td>
<td>250</td>
<td>285</td>
</tr>
<tr>
<td>Filler</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td>Admixtures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sika visocrete 1035</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Sika visocrete 5 -800</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Water-cement ratio</td>
<td>0,46</td>
<td>0,47</td>
</tr>
</tbody>
</table>

2.4 Test Specimens

The rebound hammer was used for tests on 150 mm cubes, which were taken from different storage. Tests were made at ages of 2, 7, 14, 21, 28 and 60 days.

The test specimens have been performed the following tests:
- Density of hardened concrete \( D \) (CSN EN 12390-7) [6];
- Rebound number \( R \) - for finding of affect of treatment test area to value of impact hammer has been each test area on the specimen adjustment as is shown in figure 1. On each test sample was made 36 rebound numbers for each type of impact hammer – 18 rebound number for each way preparation of test area. The measure of rebound was detected on two opposite surface of concrete specimen, respectively.
- test surface of specimen has been divided into two equal parts, respectively
- one part of cube was preparation according to the procedure EN 12504-2[2], ground flat with abrasive stone
- Second test area has been prepared according to the procedure CSN 73 1373[3], grinding by diamond wheel until the visibility of concrete structure. A prepared test specimen is shown in figure1.
- Schmidt hammer "Original" a type N and L was used for test on 150 mm cubes clamped in a compression testing machine and loaded on 10% of the ultimate strength. The measurement was made on two opposite surfaces – for each type of testing area (according
to CSN 73 1373[3], CSN EN 12390-3[7]) and 18 measurements have been made. The specimens were later crushed to provide a compressive strength value.
- compressive strength $f_{c,cm}$ (CSN EN 12390-3) [7];

![Figure 1. Detail of tested area – EN 12504[2]/CSN 73 1373[3].](image)

### 2.5 Test results

The results are summarized below and are illustrated by table 2. In this table is shown to different types of concrete, different storage used. Average differences (relative to the rebound value on an area according to CSN 73 1373[3]), standard deviation, minimal and maximal value of the difference. Average difference is difference between rebound number on the test area, which has been prepared according to CSN 731373[5] (grinding tool) and the test area prepared according to CSN EN 12504-2[2] (using only abrasive stone) individually measurement in the set; evaluation set of rebound number for specific strength class of concrete and type of impact hammer. The difference is expressed by numerical value and percentage.

In the figures 1 and 2 are given dependencies between the rebound value on the concrete cube test area for various test area treatments (treatment according to CSN 73 1373[3] – grinding) and for various ways of test specimens curing – tested with Schmidt hammer N and L.

### Table 2. Tested concretes rebound number parameters

<p>| Rebound Hammer | Standard storage | Type N | | | Type L |
|---|---|---|---|---|
| Concrete Type | C25/30 | C30/37 | C25/30 | C30/37 |
| Average difference | 1.89 | 1.95 | 2.05 | 2.02 |
| Average difference [%] | 5.7 | 4.09 | 7.29 | 4.76 |
| Standard deviation | 0.99 | 0.84 | 1.42 | 0.80 |
| Minimum | 0.3 | 0.7 | 0.1 | 1.1 |
| Maximum | 4.6 | 4.1 | 5.2 | 4.0 |</p>
<table>
<thead>
<tr>
<th>Rebound Hammer</th>
<th>“Dry” storage</th>
<th>Type N</th>
<th>Type L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Type</td>
<td>C25/30</td>
<td>C30/37</td>
<td>C25/30</td>
</tr>
<tr>
<td>Average difference</td>
<td>1.83</td>
<td>1.30</td>
<td>1.08</td>
</tr>
<tr>
<td>Average difference [%]</td>
<td>5.44</td>
<td>2.93</td>
<td>4.19</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.31</td>
<td>0.80</td>
<td>0.70</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.1</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.8</td>
<td>3.8</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Figure 2. Relation among rebound value for different test area treatment method - Schmidt hammer model N

Figure 3. Relation among rebound value for different test area treatment method - Schmidt hammer model L
4. Conclusions

The result of tests has shown influence of surface preparation method on the concrete rebound number of impact hammer test. According to CSN EN 12504-2[2], the results of number rebound of specimens stored in two storage condition have been 2 units more lower than at the treatment according to CSN 73 1373[3] – grinding machine with a diamond wheel, independently on the used of type of impact hammer. Compressive strength based on rebound number, indicated differences 3 - 4 MPa, approximately.

The results obtained of rebound number on specimens under dry condition (t = 20 - 23 °C, φ 30 - 35 %), are smaller, in average around 1, 3 points.

The test area treatment according to CSN 73 1373[3] (grinding by machine until the concrete structure is evident) has other advantages, namely:

- removes the pores in the cement mortar on the concrete surface
- the defects in a concrete structure, which may affect the test results, are visible
- the cement mortar and grains of coarse aggregate are visible
- into certain depth the carbonated concrete layer can be removed too (on the carbonated concrete the rebound values are higher than on the noncarbonated, sometimes significantly).

It has been establishment that different effect of preparation test surface of concrete, significantly is giving different compressive strength obtained from rebound number. Test surface preparation according to CSN EN 12504-2[2] is simpler though, but for this type of testing is not optimal and reliable method for estimate compressive strength. Choose adequate way in this case is essential.

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References