Abstract: At this time are exposed a lot of building concrete problems due to durability and there are necessary apply a new methods to resolve them. The concrete and/or reinforcement can be attack it by the fluids and /or ions entrance from environment: chloride attack, sulfate attack, carbonation. From these reasons many experimental researches are made. Into this paper are presented the theoretical and experimental researches regarding carbonation process diffusion into ordinary concrete and high performance concrete samples exposed at different carbon dioxide level. In function of experimental researches was the depth carbonation formula suggested by C. Bob was added up. The concrete accelerated carbonation was made by medium accomplishment with big carbon dioxide level (until 25% for ordinary concrete and at 50% for high performance concrete). The \( d \) coefficient (concentration of CO\(_2\)) from C. Bob formula was rounded. The spectrum of accelerated carbonation concrete is showed.

Key-Words: - concrete carbonation, concrete durability, accelerated carbonation, carbon dioxide, spectrum.

1 Introduction

In the last years the concrete and building materials durability concerns many specialist researchers. At this time are exposed a lot of building concrete problems due to durability and there are necessary apply a new methods to resolve them. The solutions must be concerning the complexity of the materials used and the influence of these techniques on design, building, exploitation, maintenance …

The concrete and/or reinforcement can be attack it by the fluids and /or ions entrance from environment: chloride attack, sulfate attack, carbonation … The carbon dioxide is a gas form the atmosphere. It can penetrate concretes through open pores by two ways: by air or by CO\(_2\) which are dissolved in water content in pores. When concrete is porous this type of penetration can be more fast. The CO\(_2\) react with cement and from carbonates.

The humidity entrance which contain dissolved ions (chloride in special) or carbon dioxide can produce a corrosion of reinforcement.

All of these preoccupations are starting with exactly evaluations of exposure conditions of concrete at aggressive agent from environment.

The main problem consist in none existing of a precisely evaluation method of concrete at environment agent attack.

In a reinforced or prestressed concrete element a so-called passivation layer is formed on the surface of reinforcing bars. Sometimes this passivation layer may be attached by surrounding concrete environment, so that electrical potential differences may develop along the bars: electrochemical corrosion will then take place. The progression of deterioration of an element with time is described by initial period and corrosion process period.

A numerical calculation method for initial period (time until deterioration starts) suggested by C. BOB is presented in next formula:

\[
\bar{x} = \frac{150 \cdot c \cdot k \cdot d}{f_c} \cdot \sqrt{t}
\]

where:
- \( \bar{x} \) – average depth of ordinary carbonation or chloride penetration, [mm];
- \( f_c \) – concrete compressive strength, [N/mm\(^2\)];
- \( t \) – action time of CO\(_2\), [years];
- \( c, k, d \) – coefficients which are presented in table 1.
The concrete carbonation can be explicated by pH measurement like in figure 1. Therefore, into concrete can be:

- \( \text{Ca} \ (\text{OH})_2 \rightarrow \text{pH} > 11 \), non carbonated concrete;
- \( \text{Ca} \ (\text{OH})_2 + \text{Ca} \ \text{CO}_3 \rightarrow 9.5 < \text{pH} < 11 \), the concrete carbonation were initiated;
- \( \text{Ca} \ \text{CO}_3 \rightarrow \text{pH} < 9.5 \), carbonated concrete.

At this time to establish the level of carbonation usually is used the phenolphthalein method: the phenolphthalein solution is sprayed on the sample (concrete core) extracted from concrete structure and the color is observed.

Another method which is promoted by C. BOB (and used into this laboratory researches) consist in pH determination on concrete powder which are extracted from concrete structure using a \( \Phi 10 \) drill.

2 Experimental research

The paper deals with experimental studies on the concrete carbonation through laboratory procedure known as “accelerated carbonation”. An installation was made in order to obtain a medium with high CO2 level at atmospheric pressure.

The experimental values are used to add up the \( d \) coefficient which is present in formula 1. For this reason there were take into account next parameters:

- ordinary concrete classes:
  - C 12/15 (\( f_c = 27.6 \) N/mm²);
  - C 20/25 (\( f_c = 38.8 \) N/mm²);
  - C 25/30 (\( f_c = 49.6 \) N/mm²);
- high performance concrete (BIP code) with \( f_c > 80 \) N/mm²;
- \% CO2: 0.07%; 5% and 25% for ordinary concretes;
- \% CO2: 50% for high performance concrete;
- age of test: 3x28 days;
- concrete depths: 5 mm; 10 mm; 15 mm; 20 mm.

During preparation of this concrete classes were used different water/cement ratios. There were resulting concretes with big \( f_c \) values.

The pH values obtained for three ordinary concretes types are presented into table 2 and showed into figures 3, 4 and 5.

<table>
<thead>
<tr>
<th>CO2</th>
<th>[%]</th>
<th>0.03</th>
<th>0.10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[g/m³]</td>
<td>0.36</td>
<td>1.20</td>
</tr>
<tr>
<td>( d = )</td>
<td>1.00</td>
<td>2.00</td>
<td></td>
</tr>
</tbody>
</table>

Table 1

A quantitative model of ordinary concrete carbonation process
The curing conditions for high performance concrete (BIP) sample were: 50% of CO$_2$ and 42% relative humidity to 20 °C. The pH values obtained are presented into figures 6, 7 and 8.

From diffraction spectrum of accelerated carbonation concrete it can seen the presence of SiO$_2$ (from cement and aggregates) and CaCO$_3$ like a new compound.
From charts (figures 2 … 5) studies result the following conclusions (for ordinary concretes with $f_c < 50$ N/mm$^2$):

1. the concrete carbonation was initiated for all carbon dioxide level and is supported by pH determination and the diffraction spectrum;
2. maximum efficiency regarding accelerated carbonation (at 3x28 days) is obtaining for curing condition with 25% of CO$_2$.

For concrete which have at 7 month age $f_c > 80$ N/mm$^2$ (high performance concrete – BIP code) the pH values were between 9.5 and 11.0 (figure 6, 7 and 8) that means the concretes carbonation were initialized. The raw materials had an influence on lower pH values (in special silica fume and big quantities of cement – over 550 kg/m$^3$) compared with ordinary concrete.

In according with experimental values obtained for accelerated carbonation process which presented into table 2 and formula 1, completing values for $d$ coefficient are showed into table 3.

<table>
<thead>
<tr>
<th>CO$_2$ level [%]</th>
<th>0.7</th>
<th>5</th>
<th>25</th>
</tr>
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<tbody>
<tr>
<td>$d$</td>
<td>1</td>
<td>1.75</td>
<td>2</td>
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</table>

Table 3

The $d$ coefficient for accelerated carbonation process
3 Conclusions
The theoretical model of ordinary carbonation process was adapted to accelerated carbonation process. That means the experimental researches from laboratories and theoretical formula can simulate the concrete behavior from real life.
At 3x28 days age the **concrete carbonation was initiated** for all ordinary concretes studied. This means that accelerated carbonation procedure is efficiency.
Maximum efficiency regarding accelerated carbonation (at 3x28 days) is obtaining for 25% of CO\textsubscript{2} curing condition.
The X-Ray diffraction spectrum as well as the other experimental methods, seems that the carbonation process was initiated (CaCO\textsubscript{3} is presented).
The d coefficient (concentration of CO\textsubscript{2}) from C. Bob theoretical formula was rounded with values obtained from experimental program regarding accelerated concrete carbonation process.
All of these research results have a good contribution to increase concrete structures durability regarding the carbonation with a big impact on environment and public health.

References: