

# Possibilities of Assessment of Correlation between Durability and Aeration of Aerated Concrete

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**Abstract**—The theme of this paper is based on tracking the properties of aerated concrete determine the dependency between the parameters of fresh and hardened aerated concrete (determined in accordance with standardized procedures in common use) and durability of the concrete based on observation of properties of aerated concrete. Fluctuation of values of air content in hardened and fresh concrete are observed as well as influence of this fluctuation on durability of concrete

**Keywords**—Concrete, Aerated Concrete, Durability, Correlation

## I. INTRODUCTION

THERE is a boom of aerated concrete in particular in highway and road construction. These concretes are manufactured with aerated and plasticizing admixtures and their effect enhances properties of concrete, in particular workability, water-tightness, frost resistance and surface resistance to action of water and chemical de-icers, and thus the life-time of concrete structures exposed to corrosive environment, acid rain and frost is longer.

Air-entraining admixtures create a system of pores of different sizes in concrete. These pores, called also “effective air” serve as space for expansion to eliminate pressures developed during crystallization of ice or de-icing salts. In general, desirable size of pores is considered to be between 25 – 300  $\mu\text{m}$ ; larger pores cause unproportional deterioration of mechanical properties of concrete.

Once concrete hardens, air pores stay in the form of voids. This is usually called a “system of air bubbles – pores” in hardened concrete. Main parameters of air pores are total air content, average spacing of pores and specific surface of pores. The effective air consists of small enclosed pores of microscopic size with diameter 10 to 300  $\mu\text{m}$ . These micro-pores are evenly distributed throughout the mass of concrete. Relative distance between pores is called the Spacing factor. It is the distance of travel of water before it can enter an air pore – this decreases the pressure. Specific surface indicates relative number and size of air micro-pores for given content of air. Larger value of specific surface is better since it indicates higher number of smaller pores. Spacing factor value

< 0.2mm is necessary to reach high resistance to frost and defrost. Total air content is usually measured with fresh concrete. Required air content decreases with growing gradation of aggregate.

As for aerated concrete, problems of conformity of repeated testing of aerated concrete still remains unresolved. Namely the dependence of air content of fresh concrete before placing and after placing and compaction is not determined by pressure method used with fresh concrete. There is also no correlation between air content in fresh concrete (pressure method), characteristics of air pores in hardened concrete (Spacing factor) and resistance to action of frost, water and chemical de-icers.

## II. EXPERIMENTAL PROGRAM

The topic of this paper is unification and testing of different mix-designs of aerated concrete and observation of statistical dependence between air content in fresh concrete and characteristics of space distribution or air pores in hardened concrete determined after 28 days. Air-entrainers were dosed so that the air content in fresh concrete determined by pressure test was between 4.0 and 7.0%. Air content of different mix-designs determined by pressure test was compared to air content of hardened concrete determined microscopically. Method of this test is described in the following chapter. At the same time, resistance to chemical de-icers and resistance to frost of concrete were tested in automated freezing device. After evaluation of all tests, individual curves of dependencies of tested aerated concrete were drawn and correlation relationships were described, in particular those between air content in hardened concrete determined microscopically and resistance of concrete to chemical de-icers determined in accordance with CSN 73 1326.15 mix-designs of concrete of the same composition of strength class C 30/37, degree of corrosive attack XF2 – XF4 were made for the purpose of laboratory tests. Cement used was Portland cement class 42.5 R, Mokrá, mined aggregate of fraction 0-4mm, site Tovačov, coarse mined aggregate fraction 4-8 mm site Náklo and coarse crushed aggregate fraction 8-16 mm and 11-22 mm, site Želešice. Plasticizer used was based on sulphonated condensates of naphthalene Stachment NN combined with air-entrainer Microporan by the same manufacturer. Each of the mix-designs was tested to determine properties of fresh concrete and evaluation of physico-mechanical properties of hardened concrete.

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Based on these properties, the curves of dependency were drawn.

TABLE I  
RESULTING PARAMETERS OF MIX-DESIGNS OF AIR-ENTRAINED CONCRETE

| Lbl.           | Slump<br>[mm] | Air content<br>in FC<br>[%] | Volume<br>weight FC<br>[kg/m <sup>3</sup> ] | Volume<br>weight HC<br>[kg/m <sup>3</sup> ] | Compressive<br>strength<br>28 days<br>[N/mm <sup>2</sup> ] | Resistance to water and<br>chemical de-icers |                                   |
|----------------|---------------|-----------------------------|---|---|--|--|-----------------------------------|
|                |               |                             |   |   |  | 50 cycles<br>[g/m <sup>2</sup> ]             | 100 cycles<br>[g/m <sup>2</sup> ] |
| AC1            | 170           | 6,7                         | 2400  | 2350  | 40,5   | 73,3   | 185,6                             |
| AC12           | 170           | 7,5                         | 2380  | 2330  | 39,0   | 60,5   | 95,3                              |
| AC3            | 130           | 4,6                         | 2410  | 2360  | 42,0   | 125,5  | 215,7                             |
| AC4            | 140           | 5,7                         | 2380  | 2330  | 42,5   | 108,6  | 198,3                             |
| AC5            | 190           | 7,8                         | 2360  | 2310  | 42,5   | 32,6   | 116,9                             |
| AC6            | 180           | 8,5                         | 2330  | 2290  | 39,0   | 53,9   | 89,8                              |
| AC7            | 150           | 6,5                         | 2360  | 2330  | 42,5   | 95,3   | 189,3                             |
| AC8            | 140           | 7,0                         | 2420  | 2390  | 44,0   | 25,3   | 52,5                              |
| AC9            | 200           | 7,7                         | 2380  | 2340  | 46,5   | 31,5   | 66,5                              |
| AC10           | 150           | 6,0                         | 2420  | 2390  | 50,5   | 24,3   | 54,7                              |
| AC11           | 150           | 6,5                         | 2420  | 2380  | 48,5   | 37,2   | 69,4                              |
| AC12           | 140           | 4,2                         | 2410  | 2380  | 41,0   | 65,3   | 185,6                             |
| AC13           | 180           | 7,5                         | 2380  | 2340  | 42,0   | 37,2   | 89,7                              |
| AC14           | 160           | 5,6                         | 2400  | 2360  | 45,0   | 69,3   | 189,6                             |
| AC15           | 150           | 6,1                         | 2380  | 2330  | 43,5   | 128,3  | 223,9                             |
| <b>Average</b> | <b>160</b>    | <b>6,5</b>                  | <b>2390</b>                                 | <b>2350</b>                                 | <b>43,5</b>  | <b>64,5</b>                                  | <b>134,9</b>                      |

TABLE II  
PARAMETERS OF AERATION OF FRESH AND HARDENED CONCRETE

| Lbl.           | Air content<br>in FC | Air content in<br>HC | Microscopical<br>air content<br>A300 | Spacing<br>factor<br>L |
|----------------|----------------------|----------------------|--------------------------------------|------------------------|
|                | [%]                  | [%]                  | [%]                                  | [mm]                   |
| AC1            | 6,7                  | 5,72                 | 3,02                                 | 0,13                   |
| AC12           | 7,5                  | 8,31                 | 3,34                                 | 0,16                   |
| AC3            | 4,6                  | 4,21                 | 2,86                                 | 0,11                   |
| AC4            | 5,7                  | 5,78                 | 2,40                                 | 0,13                   |
| AC5            | 7,8                  | 9,48                 | 2,96                                 | 0,11                   |
| AC6            | 8,5                  | 8,41                 | 1,44                                 | 0,19                   |
| AC7            | 6,5                  | 6,98                 | 2,53                                 | 0,13                   |
| AC8            | 7,0                  | 6,16                 | 4,35                                 | 0,09                   |
| AC9            | 7,7                  | 6,31                 | 2,86                                 | 0,14                   |
| AC10           | 6,0                  | 7,10                 | 3,22                                 | 0,11                   |
| AC11           | 6,5                  | 6,81                 | 2,01                                 | 0,15                   |
| AC12           | 4,2                  | 4,39                 | 1,82                                 | 0,12                   |
| AC13           | 7,5                  | 5,83                 | 2,16                                 | 0,13                   |
| AC14           | 5,6                  | 5,31                 | 1,66                                 | 0,20                   |
| AC15           | 6,1                  | 5,79                 | 2,31                                 | 0,14                   |
| <b>Average</b> | <b>6,5</b>           | <b>6,4</b>           | <b>2,60</b>                          | <b>0,14</b>            |

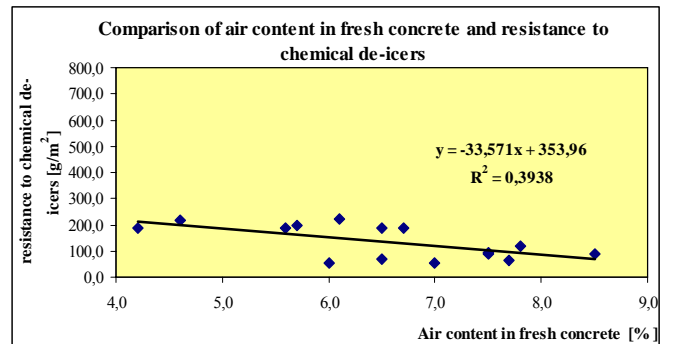


Fig. 1 Comparison of air content in fresh concrete and resistance to chemical de-icers

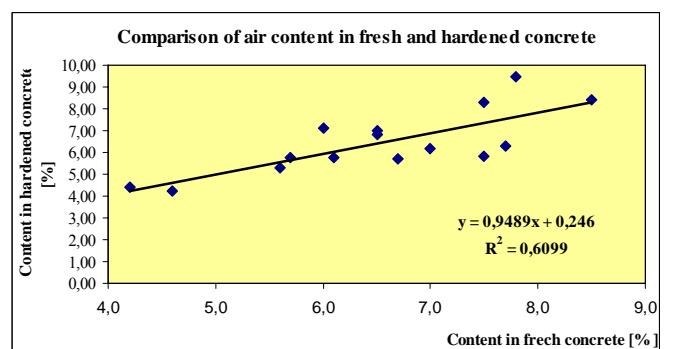


Fig. 2 Comparison of air content in fresh and hardened concrete

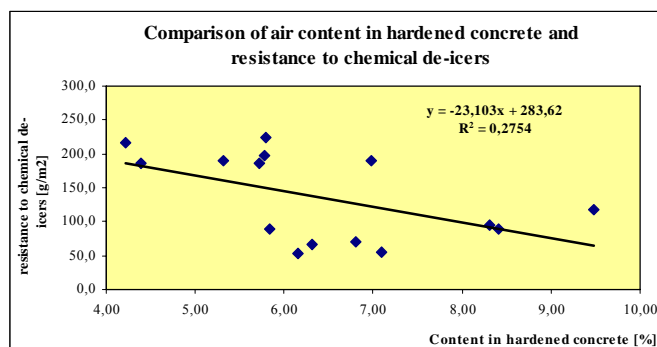


Fig. 3 Comparison of air content in hardened concrete and resistance to chemical de-icers

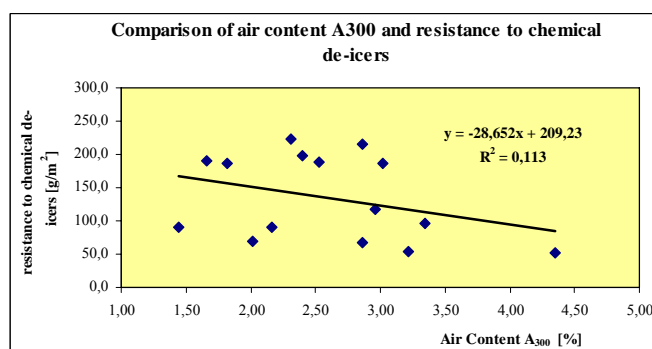


Fig. 4 Comparison of air content A<sub>300</sub> and resistance to chemical de-icers

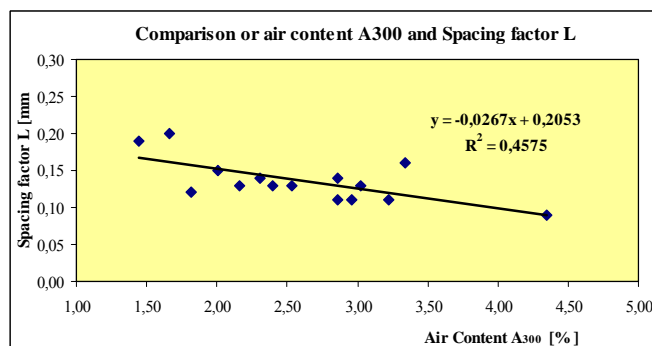


Fig. 5 Comparison of air content A<sub>300</sub> and Spacing factor L

### III. CONCLUSION

The paper deals with correlation between parameters of durability and aeration of aerated Concrete. Individual parameters of the partial correlations aerated concrete were evaluated together. Relationship between air content in fresh concrete and air content in hardened concrete showed value of correlation between observed parameters 61.0%, which indicates emergent dependency between air content in fresh and hardened concrete of observed mix-designs. Relationship between air content in fresh concrete and resistance to chemical de-icers showed correlation 39%, which means that no important interdependency can be expected between observed parameters. As for comparison of air content in

hardened concrete and resistance to chemical de-icers, the value of correlation 27.5% does not indicate any interdependency of these two properties. No dependency was found between content of microscopic air and resistance to chemical de-icers; the value of determination index was below 12%. This fact was not caused by low resistance of concrete or low content of microscopic air, but by lower compatibility of plasticizing and air-entraining admixtures. The total content of air in hardened concrete varied considerably as well as air content of microscopical air. This is in accord with other indexes, where measure of correlation between air content in hardened concrete and air content A300 was as low as 2%. Comparison of Spacing factor L and air content of hardened concrete and air content A300 showed values lower than 3%. As for the second set of properties, the level of correlation between content of microscopical air A300 and Spacing factor was 45.8%, which shows slight relationship. In general it is true that interdependence between two observed values can be considered if correlation is 60% or more. It means that no interdependence was found between the measure of aeration of fresh and hardened concrete of observed mix-designs and its durability.

Stated values imply there is no solid correlation between assessed values. It becomes clear that the currently used system cement – water – admixtures – additives is very complex and sensitive to accuracy and sequence of dosage of individual components, time and way of mixing and temperature of its constituents. Moreover the test methods used are not always exact – e.g. there is no definition and prescript for the procedure of placing concrete into pressure vessel for the purpose of measuring air content of fresh concrete or for the procedure of compacting. Treatment of surface of test samples before the test of resistance to chemical de-icers is also more or less left to a laboratory analyst. These and other factors may contribute to considerable differences of results even if the mix-designs are identical.

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