MICROSTRUCTURE AND AESTHETIC APPEARANCE OF SCC

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Abstract

Recently the development and application of self-compacting concrete has known a great growth. Most times it is expected that self-compacting concrete has better surface quality, but this is not always the case. The surface may have a lot of holes. In the case of aesthetic problems it is furthermore not sure that these blowholes are only situated at the surface or that they also occur in the mass of the concrete. In the latter case there will be not only aesthetic but also durability problems. These issues are investigated in the present paper.

1. INTRODUCTION

Blowholes appear on concrete surfaces and are the result of entrapped air or dirt. Many parameters have influence. [1] shows the importance of the formwork material and release agent, which can be of greater significance than the composition of the concrete. Formwork release agents with surface active agents, absorbent materials and a good compatibility between them are important. According to [3] entrapped air can be brought into the fresh concrete during mixing, transporting and pouring. The amount of air depends on the grading, texture and mineralogy of the aggregates. The properties of cement, filler, admixtures, water, the mixing rate, mixing time, the temperature of the environment and the fresh concrete have all their influence.

2. INFLUENCE OF FORMWORK RELEASE AGENTS AND FORMWORK MATERIAL

Table 1 gives the properties for four mixtures made with constant amounts of gravel, sand, portland cement and limestone filler. Three different superplasticizers were used. SPL3 is a regular superplasticizer, not intended for SCC. Twelve concrete elements (3 per type of concrete) were cast with dimensions 1m x 0.5m x 0.16m. The formwork material is steel. Release agents RA1 is (according to [1]) a type 2b (animal or vegetable oil with surface active agents), RA2 is a type1a (mineral oil without surface active agents), RA3 is a type 1b (animal or vegetable oil without surface active agents), RA4 is a type 2a (mineral oil with surface active agents), RA5 is also a type 1b, RA6 is a type 4 (oil in water emulsion). Each surface is provided with one of the 6 release agents in such way that for every type of concrete one surface with a different release agent exists.

Table 1: Self-compacting properties of the 4 mixtures

	concrete A	concrete B	concrete C	concrete D
W/C [-]	0,49	0,49	0,49	0,51
W/P [-]	0,29	0,29	0,29	0,31
C/P [-]	0,60	0,60	0,60	0,60
SPL 1 [l/m³]	3,67	-	-	-
SPL 2 [l/m³]	-	3,67	-	2,3
SPL 3 [l/m³]	-	-	9,24	-
Slump flow [mm]	742	673	538	683
V-funnel [s]	9,2	13,6	10	9,9
U-box difference [mm]	10	10	60	20
Volumetric mass [kg/m³]	2365	2390	2240	2365
Air content fresh concrete [%]	2,7	2,4	7,6	2,2

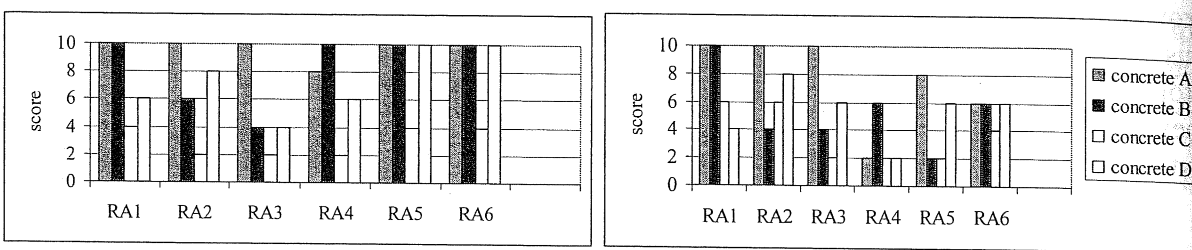

Figure 1: Results of the total number (left) and the maximum size (right) of blowholes

The total number of blowholes and the maximum size were noted during a visual inspection of the surfaces. A score going from 2 (many/ big blowholes) to 10 (none/ small blowholes) was assigned (cf. figure 1). For the evaluation of the total number of blowholes the following dropping order can be noticed: type 1b and 4, type 2b, type 1a and 2a, type 1b or type 4, type 2, type 1. This gives good similarity with the order drawn out [2]: type 1b, type 4, type 2b and 6, type 1a, type 2a and 5 or type 4, type 6, type 1, type 2, type 5. [1] confirms the negative influence of steel for type 1 and 2 on blowholes. For the evaluation of the maximum size of blowholes the following dropping order can be noticed: type 2b, type 1a, type 1b and 4, type 1b, type 2a or type 1, type 4, type 2 (small differences). For [2] is this type 1b and 6, type 4, type 2b, type 2a, type 1a, type 5 or type 6, type 1 and 4, type 2, type 5. In this research best results were achieved with type 2b (RA1) and type 4 (RA6).

3. INFLUENCE OF THE COMPOSITION OF CONCRETE

Eleven concretes with differences in the amounts of aggregates and water were made (cf. table 2). Four plastic cube moulds (150mm) with a mineral formwork release agent were cast for every type of concrete. The cubes were demoulded after one day and stored under curing conditions (>90% RM, 20±1°C) till testing time. Two surfaces of each cube were inspected for blowholes. The surface was made black with ink and the holes were filled with $BaSO_4$. A picture made with a digital camera was analysed with the standard image processing programme ImageTool. These analyses give a total blowhole percentage (cf. table 2) and a distribution in size (cf. figure 2). The surfaces have many blowholes, with rather big standard deviations. Differences in the amount of formwork release agent, the rate of casting and the time frame of casting could be the reason. There are more blowholes at the bottom of the mould due to entrapped air because of faster pouring at the beginning. Because of the enclosure of the mould it is for the air bubble also harder to escape.

Table 2: Concrete mixtures and measured parameters

SCC	1	2	3	4	5 b	6	7	9	10	12	13
sand 0/4 [kg/m³]	822	868	791	854	801	822	822	889	754	833	805
gravel 2/8 [kg/m³]	326	344	314	338	317	326	326	352	299	330	319
gravel 8/16 [kg/m³]	403	426	388	420	393	403	403	436	370	409	395
CEM I 52,5N [kg/m³]	360	300	400	360	360	300	400	300	400	360	360
water [kg/m³]	165	138	183	165	165	165	165	137	192	144	198
calcareous filler P2 [kg/m³]	240	240	240	180	280	300	200	200	300	240	240
superplasticizer [l/m³]	2.90	3.50	2.60	2.70	3.04	2.40	3.70	3.00	2.12	4.00	1.60
temp. environment [°C]	16.1	16.2	16.1	15.7	15.8	15.8	16.6	16.3	16.4	16.2	16.7
temp. mixture [°C]	20	20.3	19.5	22	22	18	22	19	20	23	19
moisture content [%]	49	50.4	50.4	45.7	46.5	46.5	48.1	51.6	40.9	40.8	48.8
mixture time [min.]	6.5	9.0	11.1	4.3	4.3	4.3	15.0	5.0	7.0	23.0	5.3
slump flow [cm]	70	67.5	67	77.5	93.3	80	64	69	58.5	60.8	74.8
V-funnel [sec.]	9.1	18.5	7.3	9.6	9.4	9.2	8.0	28.0	8.8	17.3	4.0
U-box difference [cm]	1	4	2	0.5	0.1	0.5	3.5	4	2.5	4	1
volumetric mass [kg/m³]	2393	2400	2356	2400	2363	2409	2394	2388	2356	2400	2375
strength 28d [N/mm²]	77.1	81.9	73.4	80.6	66.2	67.3	82.4	81.1	71.7	87.4	61.1
air content fresh concrete [%]	2.05	3	2.8	1.4	0.85	1.35	2.85	2.85	2.2	3.15	1.1
blowhole percentage [%]	4.54	5.64	4.46	3.46	4	4.63	4.36	6.01	4.74	6.85	2.9
total area/number [mm²]	3.69	3.68	2.98	2.32	1.91	2.89	6.18	4.65	2.95	4.90	2.99

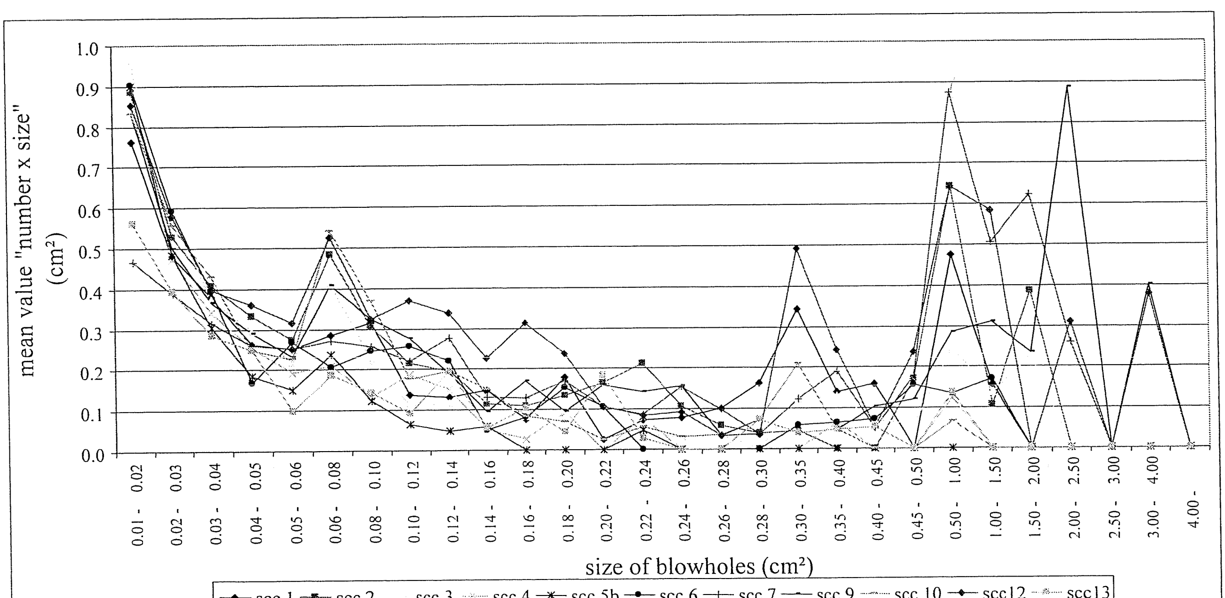

Figure 2: Distribution in size

The results show a linear relationship between the air content of fresh concrete (vol%) and the blowhole percentage (area%) of the hardened concrete with a $R^2=0.5847$. Between the air content of fresh concrete (vol%) and the total area of blowholes (cm^2) a linear relationship with $R^2=0.8093$ is found. A mixture design with low air content in fresh condition is therefore convenient.

From the distribution in size a value can be calculated by which the influence of the concrete composition can be investigated. This value is the weighted average of the distribution in size, namely the division of the total area of blowholes to the total number of blowholes. Figure 3 presents the meaning of this value: figure 3a is the lower limit, figure 3b is a normal distribution and figure 3c is the upper limit. Figure 4 arranges the concretes in order of this value. Notice that the reference concrete SCC1 lies in the middle.

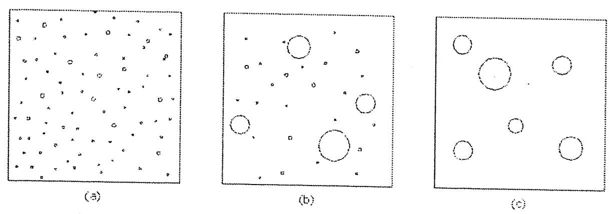

Figure 3: Possible size distributions

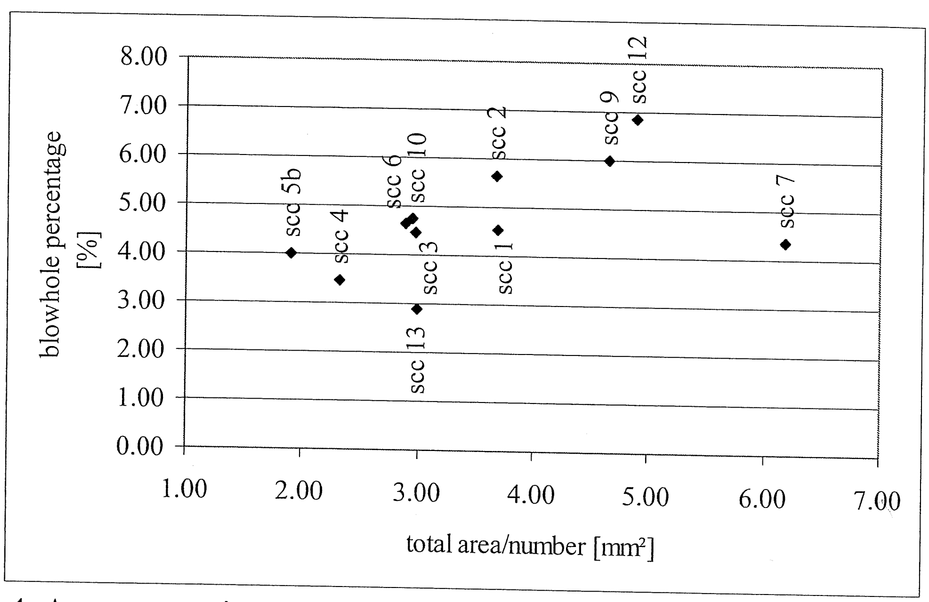

Figure 4: Arrangement in order of the weighted average of the distribution in size

The air content of fresh concrete, the blowhole percentage and the weighted average of the distribution in size have low relationship ($R^2<0.5$) with the parameters concerning the casting and composition of concrete as given in the introduction. The relationship is nevertheless around $R^2=0.9$ when the concretes are divided into groups with constant amounts in the composition of concrete. The relations were reproduced in another experiment. The amount of superplasticizer seems to have an increased effect on the presence of blowholes, while the W/C, W/P, C/P and the concrete workability (slump flow) seem to have a decreased effect. [1] also mentions a decreased effect on the presence of blowholes for the amount of cement and the workability, and an increased effect for the amount of sand. According to [3] a high flow ability in combination with a not too high viscosity is the best chance to avoid blowholes. This can be found in the experiment for the relations of the slump flow and the V-funnel.

Remarkable is the influence of the amount of superplasticizer, because the opposite could be expected when considering its influence on the increasing workability. The design methodology can explain this phenomenon. The amount of superplasticizer was estimated against the reference concrete SCC1 in such way that a drop of the workability (W/P, water content, slump flow) was corrected by a higher amount of superplasticizer. [3] remarks however that superplasticizers produce air and therefore anti-foam additives which can reduce this are added. Separation of these two components is possible.

4. RELATIONSHIP BETWEEN BLOWHOLES AND AIR BUBBLES IN THE CONCRETE MASS

From the concrete elements of table 1 a core was drilled which was sawn in 6 discs. 3 discs UP (upper part), MP (middle part) and LP (lower part) belong for the same concrete to a different release agent. The UP's are situated at the concrete surface, while the MP's and LP's are located in the concrete mass. The air content and spacing factor were measured with the RapidAir 457 according to the air void analysis ASTM C457 (cf. figure 5). This was done in 4 perpendicular directions and for 10 probe lines. The UP's were not polished because the effect of blowholes was measured here. This gives however measuring faults because the surface keeps its relief and the image produced by the objective becomes blurred. Some blowholes have also a diameter which exceeds the measuring maximum of the RapidAir (4mm). This has no effect on the measured air content but it has on the distribution in size because the blowholes with a higher diameter will be spread over different classes.

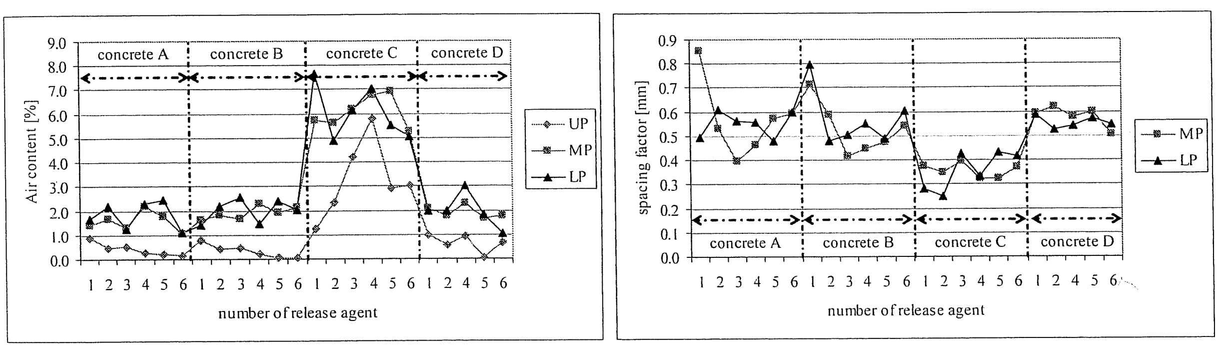

Figure 5: Air content RapidAir and spacing factors

The following conclusions can be made:

- The air contents in the concrete mass (MP and LP) have good correspondence which indicates that the concrete is homogeneous in the mass.
- The air content at the surface (UP) is lower than the air content in the mass (MP and LP).
- The air content of fresh concrete (table 1) is around the air content in the mass. Due to Transportation and pouring air can escape or can be added.

- The spacing factors in the concrete mass (MP and LP) are above the maximum of 0.2 mm for frost resistance.

Two UP samples (1B and 1D) were polished to have the air content at 1mm from the surface. With this the air content development through concrete elements could be drawn as given in figure 6(L). The air content seems to decrease from a constant value in the concrete mass to a lower value at the surface. Figure 6(R) shows a typical distribution in size for the air content in the mass of the concrete. Because of reasons as mentioned above no typical distribution can be drawn for the UP samples. This problem can be rectified with image processing techniques such as ImageTool.

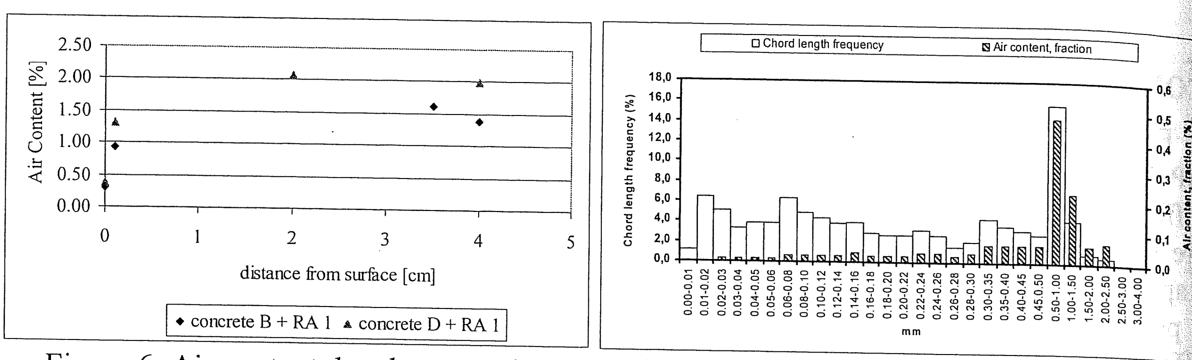

Figure 6: Air content development through the element (L) and distribution in size (R)

5. CONCLUSIONS

- Different formwork release agents have a different influence on the amount of blowholes. Type 4 (oil in water emulsion) and type 2b (animal or vegetable oil with surface active agents) show good results for steel moulds.
- The relationships found between the effect of blowholes and the composition of concrete have low R^2 values. The flow ability of the concrete is most important.
- The air content shows a drop from a constant value in the concrete mass to a lower value at the surface of the concrete.

ACKNOWLEDGEMENTS

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