FROST/DEICING SALT RESISTANCE OF CONCRETE PAVEMENTS WITH UNSUITABLE AIR VOID CHARACTERISTICS

FROST-TAUSALZ-WIDERSTAND VON FAHRBAHNDECKENBETON MIT UNGÜNSTIGEN LUFTPORENKENNWERTEN

RESISTANCE AU GEL ET AUX SELS DE DEVERGLAÇAGE DE REVETEMENTS ROUTIERS EN BETON AUX PARAMETRES DES PORES GROSSIERS MAL APPROPRIES

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ABSTRACT

In the framework of arbitration investigations on the structure, air void characteristics have been measured on several specimens of a concrete pavement which did not fulfil the requirements of the design rules completely and which questioned the durability of concrete against frost/deicing salt action. That is why additionally to the air void counting frost deicing salt tests were carried out on concrete specimens and the results were compared with pavement concrete with suitable characteristics. It has been shown that the required air void characteristics were on the safe side as expected and that sufficient frost deicing salt resistance could be reached. When the deviations from the required values were greater a significant impairment of the frost deicing salts of the tested specimens could be detected.

ZUSAMMENFASSUNG

Im Rahmen von Schiedsuntersuchungen am Bauwerk wurden an mehreren Proben eines Fahrbahndeckenbetons Luftporenkennwerte festgestellt, die nicht vollständig den Anforderungen der Regelwerke entsprachen und die Dauerhaftigkeit des Betons gegenüber Frost-Tausalz-Beanspruchung in Frage stellten. Daher wurden ergänzend zu den Luftporenzählungen Frost-Tausalz-Prüfungen an Betonproben durchgeführt und mit den Ergebnissen von Straßenbeton mit geeigneten Kennwerten verglichen. Es wurde anhand der Prüfergebnisse gezeigt, dass die geforderten Luftporenkennwerte erwartungsgemäß auf der sicheren Seite liegen und bei geringeren Abweichungen noch ein ausreichend hoher Frost-Tausalz-Widerstand vorhanden war. Wurden die Abweichungen von den

Sollwerten größer stellte sich keine allmähliche, sondern eine sehr deutliche Verschlechterung des Frost-Tausalz-Widerstandes der geprüften Proben ein.

RESUME

Dans le cadre d'une enquête d'arbitrage sur ouvrage, les paramètres de porosité grossière de plusieurs éprouvettes prélevées sur un revêtement routier en béton ne répondaient pas entièrement aux exigences prescrites par les réglementations, et mettaient en question la durabilité du béton face au gel et aux sels de déverglaçage. C'est pourquoi, en plus de l'analyse microscopique des pores, des essais de gel en présence de sels de déverglaçage ont été réalisés sur des éprouvettes de béton, les résultats ont été comparés avec ceux provenant de revêtements en béton aux caractéristiques poreuses adéquates. Avec les résultats obtenus, il a pu être prouvé que, comme attendu, les valeurs requises pour les paramètres caractéristiques des pores sont du côté sûr et que la résistance au gel et aux sels de déverglaçage obtenue pour de légères différences était suffisante. Pour des écarts plus importants, une détérioration abrupte et non pas graduelle de la résistance au gel et aux sels de déverglaçage a été observée.

KEYWORDS: frost resistance, deicing salt resistance, air voids, testing

1 COMMENTS ON THE AIR VOID CHARACTERISTICS

Extensive and long lasting experiences with respect to the high frost deicing salt resistance of concrete are available which are the basis of guidelines of concrete and concrete pavement construction [1, 2, 3]. Concrete which fulfils the requirements of the guidelines has to have a suitable pore void system which is generated by the addition of air entraining agents. These artificially introduced air voids serve as expansion space when water gets ice and increases its volume. Furtheron they interrupt capillar pores and the capillary suction is decreased. An air void system in concrete is only suitable if the following requirements are fulfilled [4], see Table 1.

Table 1: Requirements on air void characteristics in hardened concrete according to [4]

Type of testing	Micro air void content A_{300} % by vol.	Spacing factor L mm
Suitability testing	≥ 1.8	≤ 0.20
Conformity testing	≥ 1.5	≤ 0.24

The spacing factor and the micro air void content serve as air void characteristics which can only be determined on hardened concrete. The spacing factor is a characteristic value which is derived from an idealised pore void system and which determines the distance of a point within the hydrated cement paste from the nearest air void [5]. The micro air void content is the content of micro pores up to 0.3 mm diameter because only air voids up to 0.3 mm diameter are effective in concrete [6]. Both characteristic values have to be fulfilled if the concrete should be frost and deicing salt resistant.

1.1 The concretes used

The constituent materials and the composition of the concretes were chosen according to the requirements of ZTV Beton-StB [3]. The compressive strength of the investigated concretes was similar and followed the strength class B 35 according to [7] and C 30/37 according to [1] resp.

1.2 Air void characteristics of the testes specimens

In the framework of arbitration investigations according to ZTV Beton-StB [3] numerous concrete cores were investigated with respect to their air void characteristics according to [8, 9]. Prisms of the dimensions 140 mm x 30 mm x 40 mm were sawn from drilled cores the concrete surface which was exposed to frost and deicing aggression. Fig. 1 shows a situation of a drilling core and the two prisms which were taken from the cores.

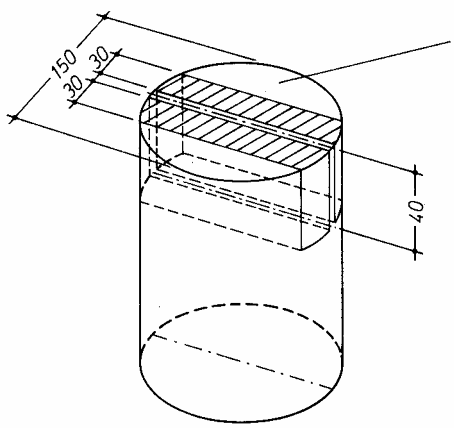


Figure 1: Two prisms about 140 mm x 30 mm x 40 mm from drilling core with a diameter of 150 mm

The sides of both prisms with dimensions 140 mm x 40 mm were finely ground. After the procedure, the pore counting has been done under a microscope. The measuring length was 1.2 to 2.4 m per drilling core according to the requirements from [8].

All specimens showed a sufficient spacing factor, however half of the specimens showed micro air void content A_{300} which was a little under the limiting value.

Table 2 shows the results of selected concretes which were subject to a frost deicing test.

The specimens of series R and the comparative specimens Ki of another structure fulfilled the requirements on the air void characteristics. However, the specimens of series N had a too little micro air void content A_{300} but fulfilled the requirements on the spacing factor.

Table 2: Air void characteristics of concrete which were subject of a frost/deicing test according to [10]

Specimen	Total air pore volume [a] A % by vol.	Micro air void content A_{300} % by vol.	Micro air void content A_{200} % by vol.	Spacing factor L mm
R-03	3.9	1.5	1.0	0.17
R-06	3.4	1.5	1.2	0.15
R-07	3.8	1.6	1.1	0.17
N-09	3.0	0.8	0.6	0.22
N-10	3.6	0.8	0.7	0.23
N-11	3.1	0.8	0.7	0.23
Ki	4.3	2.0	1.6	0.14
Requirement [b]	-	≥ 1.5	-	≤ 0.24

[a] All spherical and almost spherical air voids up to a diameter of 4 mm

[b] Requirement in the framwork of conformity testing

Table 2 contains the micro air void content A_{200} which is another characteristic value. This value correlates with the spacing factor as well as with the micro air void content A_{300} and can be calculated according to [11]:

$$A_{200} = \frac{0.299}{L} - 0.37 \tag{1}$$

The micro air void content A_{200} is important for the following evaluation of the results.

The results of Table 2 are plotted in Fig. 2 which is taken from [11]. All values (A_{300}/L) which lie within the scatterband of micro air void content A_{300} are situated above the spacing factor L.

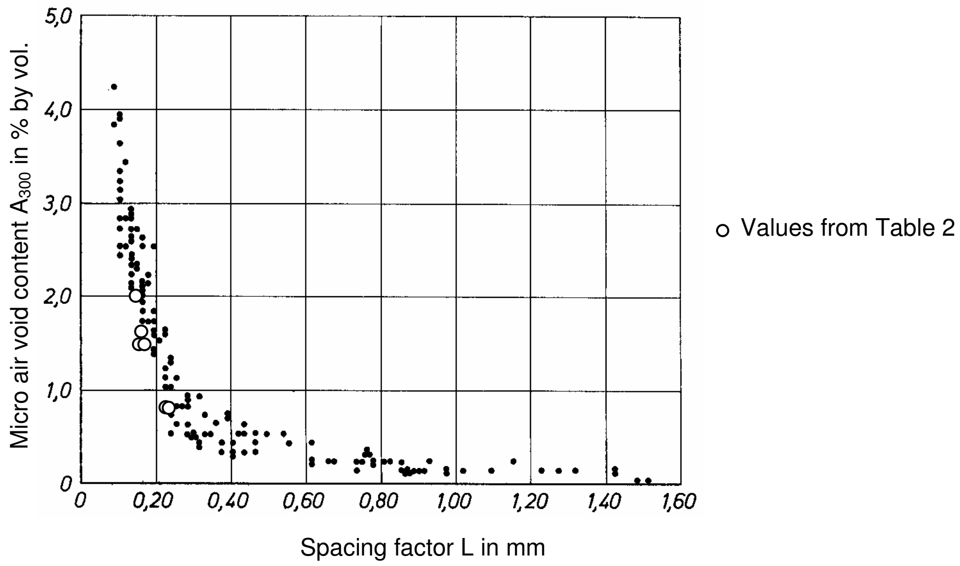


Figure 2: Spacing factor L depending on micro air void content A_{300} for concretes with various compositons (with and without air entraining agents).

2 FROST/DEICING SALT RESISTANCE

From the drilling cores a 50 mm thick slice were sawn and exposed to frost deicing test. The testing surface was the lower surface about 50 mm below the upper surface. The test method used was a Swedish testing standard SS 137244 [10] which is partly taken as European testing standard EN 12390-9 [12] as a reference method.

After 7, 14, 28, 42 and 56 testing cycles the scaling of the tested surface is determined and testing fluid (3% NaCl) was refreshed. The testing ended usually after 56 cycles. The test result is the scaling amount dried at 105°C over 24 h which is given in kg/m².

Table 3 shows the scaling amount and the frost deicing salt resistance reached. The scaling amounts are plotted vs. the number of frost deicing cycles in Fig. 3. The condition of selected specimens before and after the test are shown in Fig. 4 to 7.

Table 3: Scaling amount in kg/m² of the frost deicing salt testing according to [10]

Speci men	Scaling of concrete in kg/m² after no. of frost cycles					Ratio	Visual description after 56 frost deicing cycles	Rating of frost deicing resistance acc. to [10], Table 4
	7 (m_7)	14 (m_{14})	28 (m_{28})	42 (m_{42})	56 (m_{56})	m_{56}/m_{28}		
R-03	0.01	0.05	0.1	0.12	0.15	1.5	Litte scaling visible	Good
R-06	0.09	0.16	0.22	0.26	0.27	1.3	Litte scaling visible	Good
R-07	0.03	0.07	0.12	0.13	0.14	1.2	Litte scaling visible	Good
N-09	0.12	0.61	1.83	3.32	4.56	2.5	Separation of several grains. These remain mostly complete (failure of fine mortar matrix).	Insufficient
N-10	0.05	0.14	0.29	0.42	0.53	1.8	Punctual separation of smaller grains. Only little scaling visible	Acceptable
N-11	0.04	0.10	0.15	0.16	0.17	1.1	Litte scaling visible	Good
Ki	0.01	0.03	0.05	0.06	0.07	1.3	No scaling visible	Very good

Table 4: Rating of frost/deicing salt resistance after 56 cycles [10]

Rating	Criteria
Very good	Scaling amount ≤ 0.10 kg/m²
Good	Scaling amount ≤ 0.20 kg/m² or scaling amount ≤ 0.5 kg/m² and $m_{56} / m_{28} \leq 2$
Acceptable	Scaling amount ≤ 1.00 kg/m² and $m_{56} / m_{28} \leq 2$
Insufficient	Criteria for „acceptable“ not reached

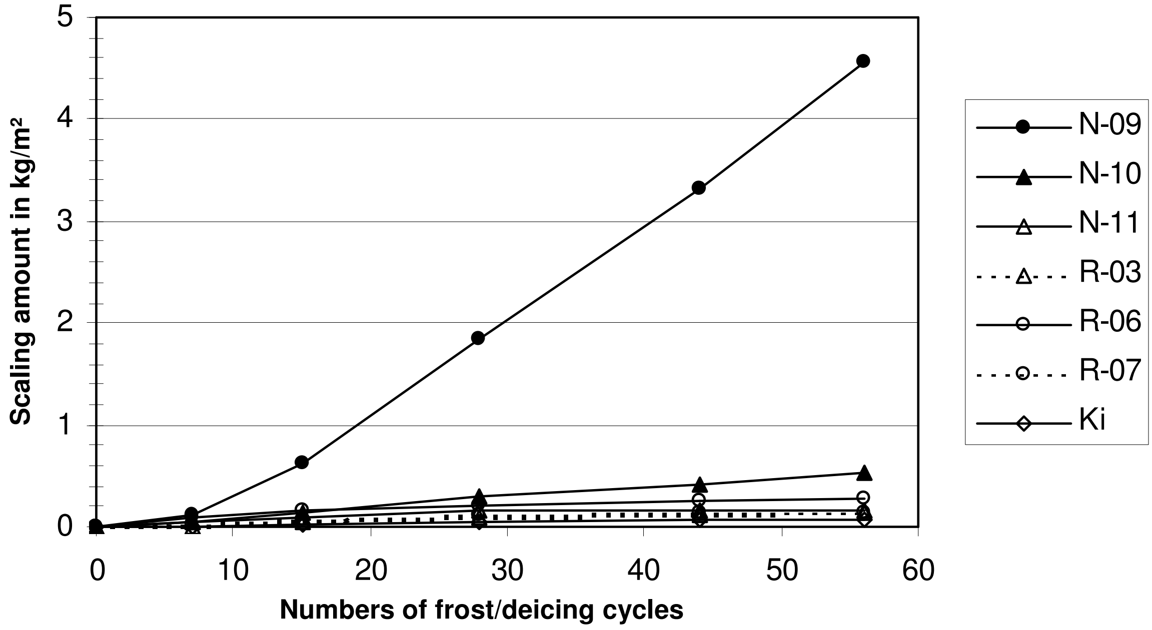
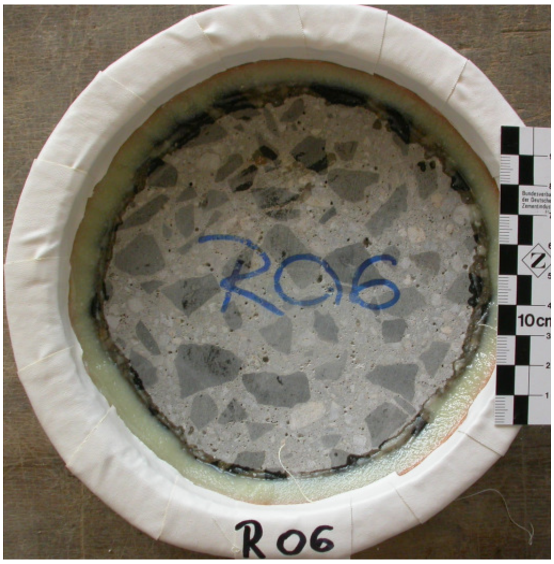
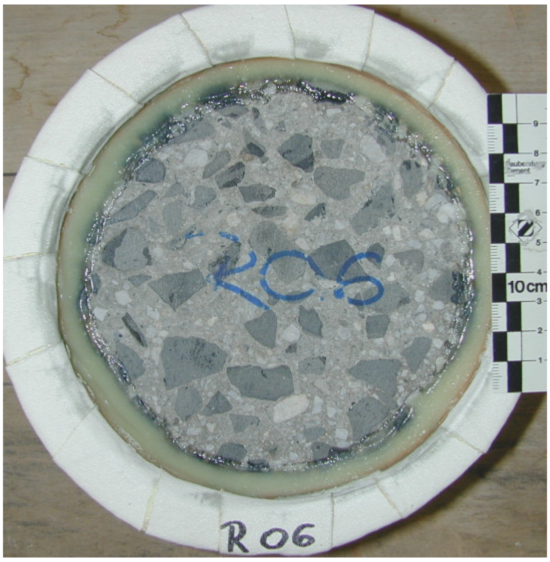
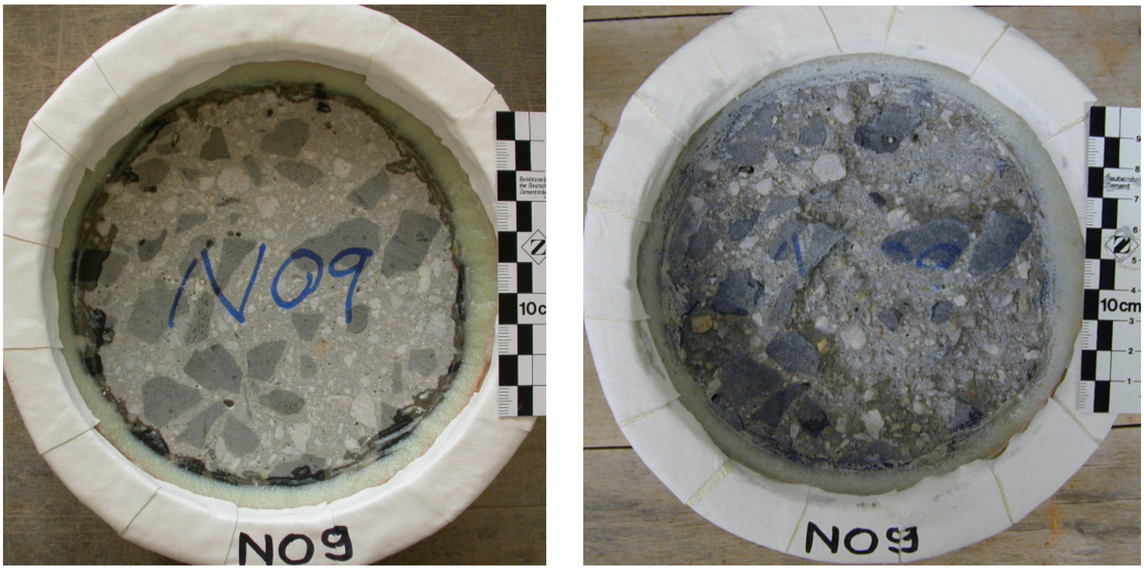


Figure 3: Scaling amount of air entrained concrete according to [3] with similar compressive strength from deicing salt test according to [10]





Figs. 4 and 5: Condition of specimen R-06 before and after frost/deicing salt testing



Figs. 6 and 7: Condition of specimen N-09 before and after frost/deicing salt testing

3 RATING

The specimens of series R (R-03, R-06, R-07) and Ki showed good or very good resistance of frost/deicing aggression which had to be expected from the suitable air void characteristics. The specimens N-10 and N-11 showed an acceptable to good frost/deicing salt resistance in spite of too little micro air void content whereas the specimen N-09 showed severe damage in the frost/deicing test. Therefore was a frost/deicing resistance according to [10] insufficient.

The concretes of series N with a spacing factor below 0.24 mm showed a too little content of micro air voids A_{300} according to [4]. Despite of that all specimens with the exception of specimen N-09 showed a sufficient to good result in the frost/deicing salt test. Also the specimens of series R with a too low spacing factor and little micro air void content A_{300} near to the limiting value of 1.5 % by vol. resulted in a high frost/deicing resistance.

The air entraining agents of today on the synthetic base tend to a finer pore structure and result in the air void characteristics as shown. With this pore structure, pores around 150 µm are present which contribute to very suitable values of the spacing factor but they do not contribute or do little contribute to the micro air void content A_{300}. The fine air pores lead to a sufficient frost/deicing salt resistance although they have a smaller air pore content.

This cannot be generalized as the behaviour of specimen N-09 showed. In this case, the content of micro air voids was too low, especially as micro air void content A_{200} is concerned and also the smallest content of total air voids.

4 SUMMARY

One can conclude that the spacing factor is the decisive value for the frost/deicing resistance of an air entrained concrete. The content of micro air voids A_{300} is a possible additional criterion for concretes with a fine pore structure. However, it should not be neglected as specimen N-09 has shown. A certain minimum amount of micro air voids A_{300} has to be reached also with a suitable (low) spacing factor. This statement cannot be applied to all air entrained concretes because concretes according ZTV Beton-StB [3] have to fulfil strong requirements on the constituents of concrete and the compositon and the concreting procedure which contribute also to high frost/deicing salt resistance.

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