Per-Erik Petersson

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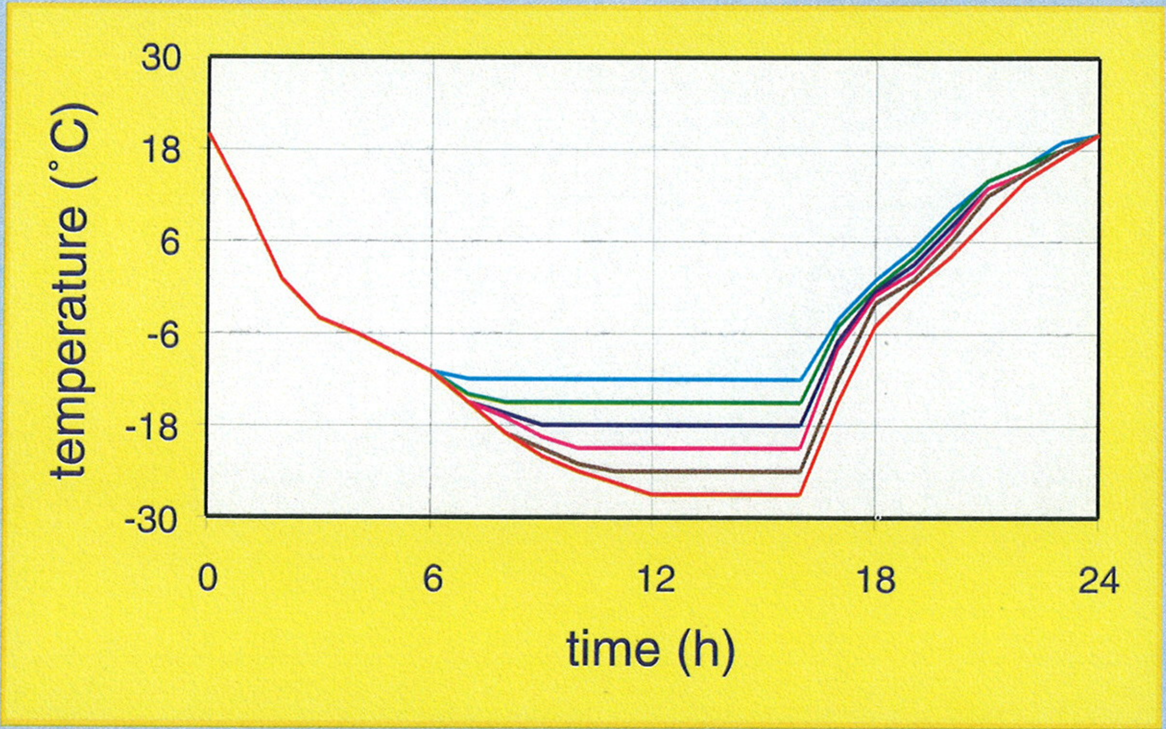
Influence of Minimum Temperatures on the Scaling Resistance of Concrete.

Part 1: Portland Cement Concrete.



SP
Swedish National Testing and Research Institute
Building Technology
SP REPORT 1994:22

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Influence of Minimum Temperatures on the Scaling Resistance of Concrete.

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Abstract

In this project, the influence of the minimum temperature of the freeze-thaw cycle on the scaling resistance of concrete was investigated. The tests were performed according to SS 13 72 44, often called the Scandinavian slab method, and minimum temperatures between -12 and -27°C were studied. All the tests were performed on Portland cement concrete qualities.

Three concrete qualities were used. These can be classified as having poor, acceptable and good scaling resistance respectively. Specimens were preconditioned in two different ways; some specimens were allowed to dry for seven days before the start of the test while others were kept in plastic bags until the start of testing. Sawn surfaces were used for most of the specimens, but for some the test surface was cast against the inside of steel moulds.

According to the test results, scaling is dependent on the minimum temperature but the dependence seems to be negligible when the following two conditions are fulfilled; the scaling exceeds about 500-1000 g/m² and the minimum temperature is below about -18°C. When these two conditions are fulfilled, the coefficient of variation, under repeatable conditions, seems to be about 10%. The results also indicate that the scaling is strongly influenced by the method of precondition and of the type of test surface.

There seem to be some advantages to preconditioning in plastic bags. The results are less dependent on the minimum temperature, the precision improves, the scaling seems to be proportional to the number of freeze thaw cycles and it is easy to obtain and maintain the correct climatic conditions. A new preconditioning method can only be used if it leads to results that rate concrete in correct order according to the performance of real outdoor concrete structures. This means that a new preconditioning method must rate concrete in the same way as when the standard preconditioning procedure is used, as the latter has been proven suitable and is based on long experience.

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Preface

The Scandinavian slab test method for testing the scaling resistance of concrete was developed at the Swedish National Testing and Research Institute (SP). The method has proved to be suitable for its purpose and it is proposed to be the European reference method for scaling resistance testing. It can, however, be further developed and the work presented in this report is an attempt to improve the method, especially with regard to the precision.

The work was performed at the Concrete section at SP during the spring of 1994. The experiments were planned and managed by Gert-Olof Johansson and the scaling tests were performed by Sten Johansson.

May 1994

Per-Erik Petersson

1 Introduction

There are a number of test methods used for determining the scaling resistance of concrete, for example the Scandinavian slab method /1/, the German cube method /2/, the German CDF-method /3/, the ASTM-method C 672 /4/. Results from comparative testing /5,6/ show that there is a relatively low precision of the test methods, both between and within laboratories. It has been proposed that the wide scatter may be a result of the fact that the minimum temperature of the freeze-thaw cycle is allowed to vary too widely and that the temperature cycle ought to be more precisely defined.

The main purpose of this project was to study how the minimum temperature of the freeze-thaw cycle affects the scaling results. Other purposes were to study the precision of the used test method, i.e. the Scandinavian slab method, to study the influence of different preconditioning methods and to investigate the effect of the type of test surface on the test results.

According to /7/ the scaling resistance is strongly dependent on the minimum temperature, and the effect is much more pronounced in the range -16- -18°C than in the range -11- -13°C. It is, however, unclear to what extent other parameters than the minimum temperature affected the results. Different lengths of the temperature cycles were used as well as different freezing rates for test series with different minimum temperatures. The investigation also was limited to minimum temperatures above -18°C while the investigation presented in this report includes minimum temperatures down to -27°C.

Another investigation carried out at the Lund Institute of Technology /8/ also indicates that the minimum temperature has a significant influence on the test results.

The investigation presented in this report deals with Portland cement concrete qualities only. Other binders such as blast furnace slag cement or concrete containing fly ash or silica fume may lead to different results.

2 Concrete mixes

Three concrete qualities were used in this investigation and the intention was to produce concrete with good, medium and poor scaling resistance. The three qualities are presented in table 1.

TABLE 1 The three concrete qualities used for studying the influence of the minimum temperature on the scaling resistance of concrete.

	Quality A	**Quality B**	**Quality C**	**Accept. dev.**
Cement (kg/m³)	400	340	420	±10
Water-cement ratio	0.45	0.55	0.45	±0.02
Aggregate (kg/m³)	1700	1758	1765	±25
Air (%)	5	4	1.8	±0.2
Air entr agent	Cementa 88L	Cementa 88L	-	
Plasticizer	-	-	-	
Slump (mm)	80	80	80	±10

The cement used was a sulphur resistant ordinary Portland cement with a low alkali content and a low value of the heat of hydration (Degerhamn anläggnings-cement). This cement has proved, according to Swedish experience, to be suitable for producing concrete with good scaling resistance. The chemical composition of the cement is presented in appendix 1.

The aggregate used was a frost resistant natural gravel with a maximum particle size of 16 mm. The air entraining agent used, Cementa 88L, is a neutralised Vinsol Resin. No other admixtures were used.

Each quality was produced in two batches at two different occasions. The first batch was used for studying the scaling resistance at -12, -18 and -24°C and the second at -15, -21 and -27°C. The concrete was mixed in a paddle mixer with a capacity of 250 litres. The mixing time was 180 seconds.

The compressive strength values measured on dry 150 mm cubes according to the Swedish standard test method SS 13 72 10 are presented in table 2.

TABLE 2 The compressive strength for the concrete qualities used. Each value represents the mean of three specimens.

	Compressive strength (MPa)	
Concrete quality	Batch 1	Batch 2
A	56.4	57.0
B	45.5	46.4
C	65.0	65.3

3 Specimen preparation

All scaling tests were performed on specimens with the dimensions 50x150x150 mm. Three different ways of preparing the specimens were used:

Method 1 (according to SS 13 72 44)
150 mm cubes were cast in steel moulds according to the procedure described in SS 13 72 44. Directly after casting the cubes were covered with plastic sheets in order to prevent evaporation from the concrete surface. 24 hours after casting the cubes were demoulded and placed in a water bath with the temperature +20±2°C where they were stored until the concrete age reached seven days. Then the specimens were placed in a climate chamber with a temperature of +20±2°C, a relative humidity of 50±5% and a wind velocity <0.1 m/s.

After 21 days an approximately 50 mm thick specimen was sawn from each cube so that the saw cut was located perpendicular to the top surface of the cube and 50 mm from one of the sides of the cube, see figure 1. Directly after sawing the specimen was washed in tap water, the excess water was wiped off with a moist sponge and then it was immediately returned to the climate chamber where it was stored for 7 days.

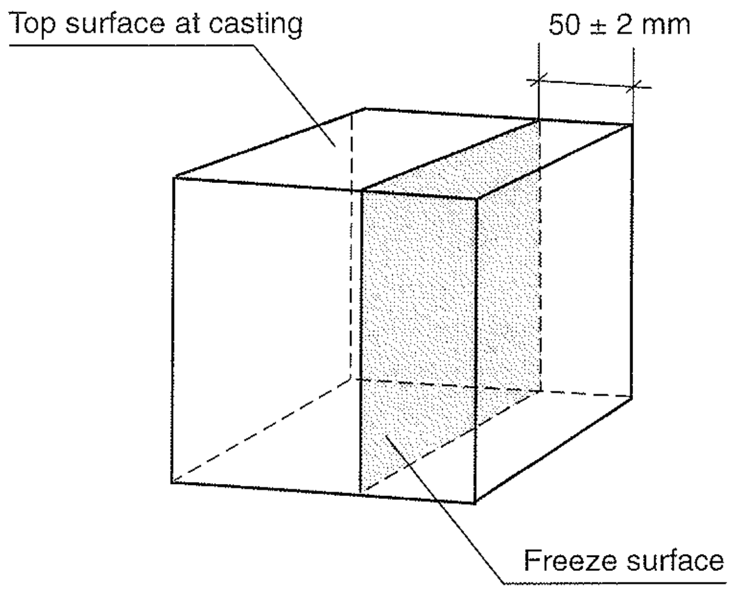


FIGURE 1 According to method 1, the specimen was sawn perpendicular to the top surface of the cube so that the saw cut for the freeze surface was located 50 mm from one of the sides of the cube.

When the concrete was 26 days old, a rubber sheet was glued to all surfaces of the specimen except the test surface according to the procedure in SS 13 72 44. The edge of the rubber reached 20±1mm above the test surface , see the test set-up in figure 2.

When the concrete was 28 days old, an about 3 mm thick layer of tap water was poured on the test surface. This resaturation continued for 72±2 hours at 20±2°C. The water was then replaced with 3% NaCl-solution and the freeze-thaw test begun.

This method was used for all the three concrete qualities.

Method 2 *(no drying before testing)*
For the first two days, the procedure was identical with the one described in method 1, after which it was modified. After two days the cubes were taken from the water bath and a 50 mm thick specimen was sawn from each cube. The saw cut was located vertically 50 mm from one of the sides of the cube. Directly after sawing the specimen was washed in tap water, the excess water was wiped off with a moist sponge and then it was immediately placed in a plastic bag which prevented evaporation from the specimen. The specimen was then stored in the plastic bag until the time for resaturation at 28 days. It was, however, removed from the plastic bag for a short time 26 days after casting in order to glue the rubber sheet to the sides of the specimen. During this period the test surface of the specimen was covered with a plastic sheet in order to prevent the surface from drying.

After 28 days this method was identical with method 1.

This method was used for concrete qualities A and C.

Method 3 *(test surface = surface cast against the mould)*
Method 3 is identical with method 1 but the test surface is the surface cast against one of the inner sides of the steel mould and not a sawn surface. A thin layer of demoulding agent was used to make it possible to demould the cube without damaging the test surface.

This method means that the test surface was dried for three weeks before the start of resaturation. The corresponding times for the other methods are 1 week for method 1 and no drying at all for method 2.

This method was used only for concrete quality B.

4 Test procedure

The freeze-thaw test was performed according to SS 13 72 44 but with different temperature cycles.

Directly after the resaturation period, i.e. when the concrete was 31 days old, all surfaces of the specimen except the test surface were thermally insulated with 20±1 mm thick polystyrene cellular plastic according to the test-set-up in figure 2. Then a 3 mm thick layer of a solution of 3% sodium chloride in water was poured onto the test surface. The solution was prevented from evaporating by applying a flat, horizontal polyethylene sheet as shown in the figure.

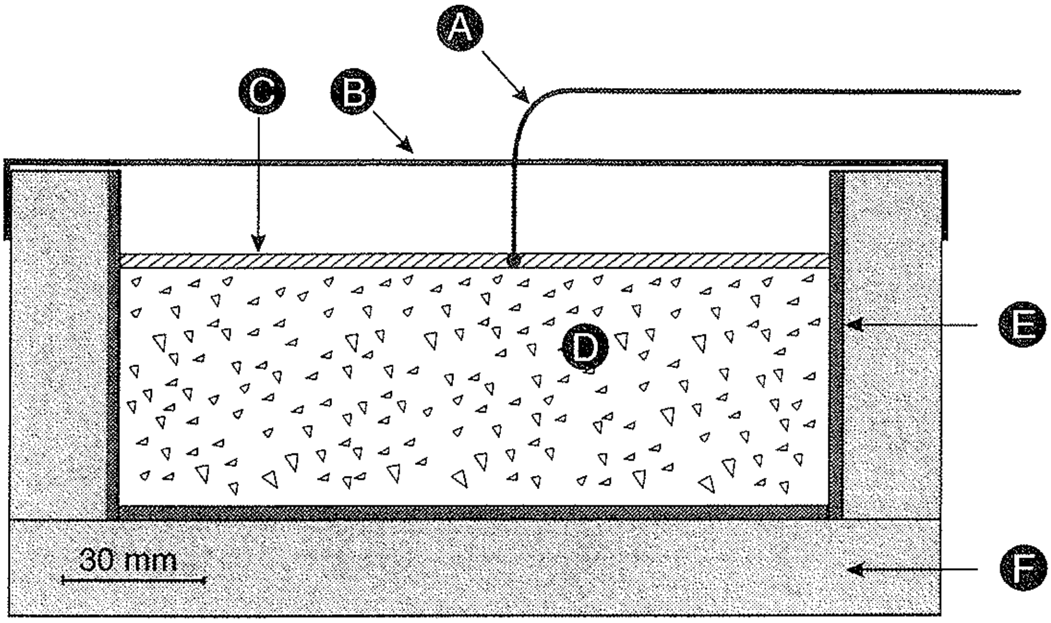


FIGURE 2 Test set-up used for the freeze-thaw tests. A=temperature measuring device + sensor for the thermostat, B=polyethylene sheet, C=salt solution, D=specimen, E=rubber sheet, F=thermal insulation.

After the specimens had been placed in the three freezing chambers used, they were subjected to repeated freezing and thawing. The temperature was continuously measured in the salt solution for one specimen in each freezer.

To obtain correct minimum temperature, a sensor for a thermostat was placed in the salt solution. When the correct minimum temperature was reached the thermostat switched the freezer off, after which the temperature was controlled by use of the thermostat. The variation of the minimum temperature for the specimens in a freezer was checked, and normally this variation could be kept within ±1°C.

When the freezer is controlled by the temperature in the salt solution, the freezer operates at constant full effect all the time until the correct minimum temperature in the solution is reached . This means that the temperature in the salt solution decreases more rapidly than when the freezer is controlled by the temperature in the air. In the latter case the freezer operates at full effect until the temperature in the air reaches a prescribed value. This normally happens before the correct minimum temperature in the salt solution is reached. This means that the temperature cycles in this investigation differ slightly from the temperature cycle prescribed in SS 13 72 44, even when the minimum temperatures is the same, i.e. -18°C.

The temperature cycles used in this investigation are shown in figure 3.

After 7, 14, 28 and 42 cycles the scaled material was collected and dried at +105°C, after which the weight was measured. The results are given as the amount of scaled material per unit area. Normally the tests are continued until 56 cycles, but owing to lack of capacity this was not possible in this investigation.

For each combination of concrete quality and preconditioning method, a series of four specimens was tested.

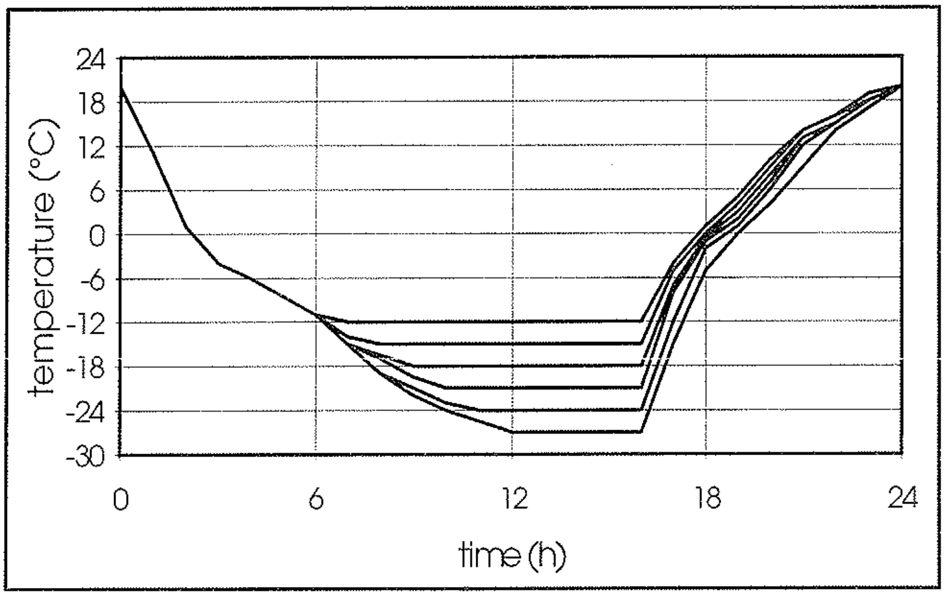


FIGURE 3 Temperature cycles used in this investigation.

5 Results

5.1 Introduction

All the individual test results are presented in appendix 2.

In the presentation below, the different series of four specimens are identified by a combination of a capital letter and a figure, for example A2. The letter gives the concrete quality while the figure defines the method of preconditioning.

5.2 Influence of the minimum temperature

The results for the different combinations of concrete quality, preconditioning of specimens and minimum temperature are shown in figures 4-9. In the figures, the scaling is plotted as functions of the number of cycles. The following comments can be made:

- *A1 (quality A, sawn surface, dried 7 days before testing)*
  All the results are below 100 g/m² after 42 cycles which, according to SS 13 72 44, corresponds to very good scaling resistance. The scaling seems, however, to be significantly dependent on the minimum temperature. The lower the temperature, the higher the scaling. This is the case for five of the six minimum temperatures, the only exception is the minimum temperature of -27°C. The results in this investigation do not provide any explanation for this exception, it may be by chance.

- *A2 (quality A, sawn surface, no drying before testing)*
  In this case the scaling is high, more than 2000 g/m² after 42 cycles for most of the series. It is obvious that there is a temperature dependency, at least when the minimum temperature is higher than -18°C. The minimum temperatures -12 and -15°C give the two lowest scaling values. For lower values for the minimum temperature, the influence of the temperature seems to be small.

- *B1 (quality B, sawn surface, dried 7 days before testing)*
  The results of this series are similar to the results of A1. The scaling is low and there seems to be a temperature dependency. For five of the six series the scaling is higher with lower minimum temperatures. The only exception, again, is -27°C.

- *B3 (quality B, surface cast against mould, dried 21 days before testing)*
  The scaling is between 100 and 500 g/m² after 42 cycles. There seems to be a strong temperature dependency for minimum temperatures above -18°C. For lower minimum temperatures the influence seems to be much less pronounced.

- *C1 (quality C, sawn surface, dried 7 days before testing)*
  This is poor quality, and the scaling is high for all minimum temperatures. There seems to be a temperature dependence but only for minimum tempera-

tures above -15°C. For lower minimum temperatures, the influence appears to be negligible.

- *C2 (quality C, sawn surface, no drying before testing)*
  The results are the same as for C1; high scaling and no influence of the minimum temperature for higher temperatures than -15°C.

The results are summarised in figure 10. In the figure, the scaling after 42 cycles is plotted against the minimum temperature.

According to the test results there appears to be an influence of the minimum temperature on the scaling resistance, which means that the lower the minimum temperature, the higher the scaling. The influence is, however, small and probably also negligible when the two following conditions are fulfilled; **the scaling exceeds about 100-1000 g/m² after 42 cycles and the minimum temperature is below -18°C.**

The results are primarily relevant for the type of concrete and the cement used in this investigation. Other cements or binders may give rise to other conclusions. It would, however, be interesting to study whether it is possible to obtain a scaling resistance test with better precision by using lower minimum temperatures, for example -20--24°C instead of -15 - -18°C, which is customary today.

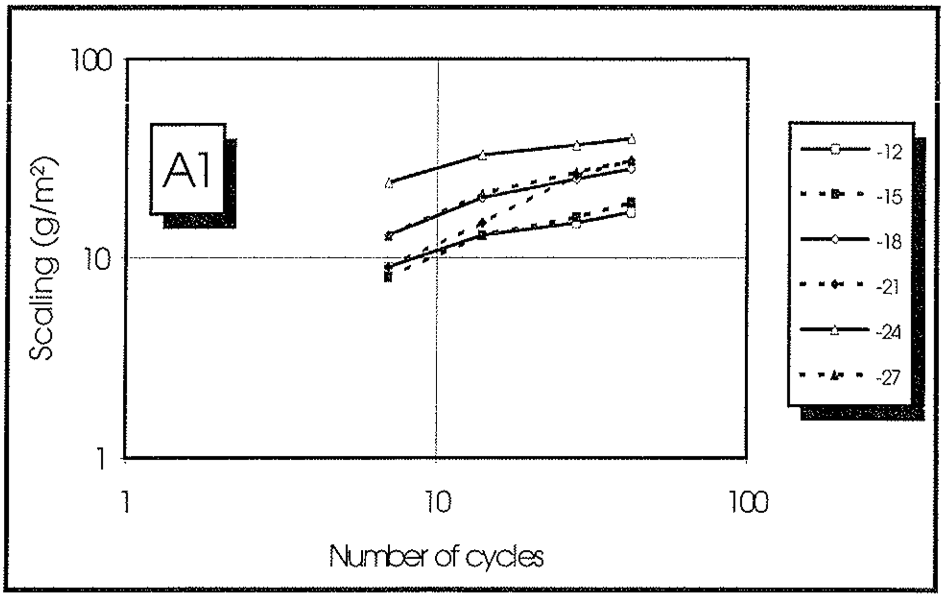


FIGURE 4 Scaling as a function of the number of freeze-thaw cycles for different values of the minimum temperature. The results are relevant for A1 (quality A, sawn surface, dried for 7 days before testing).

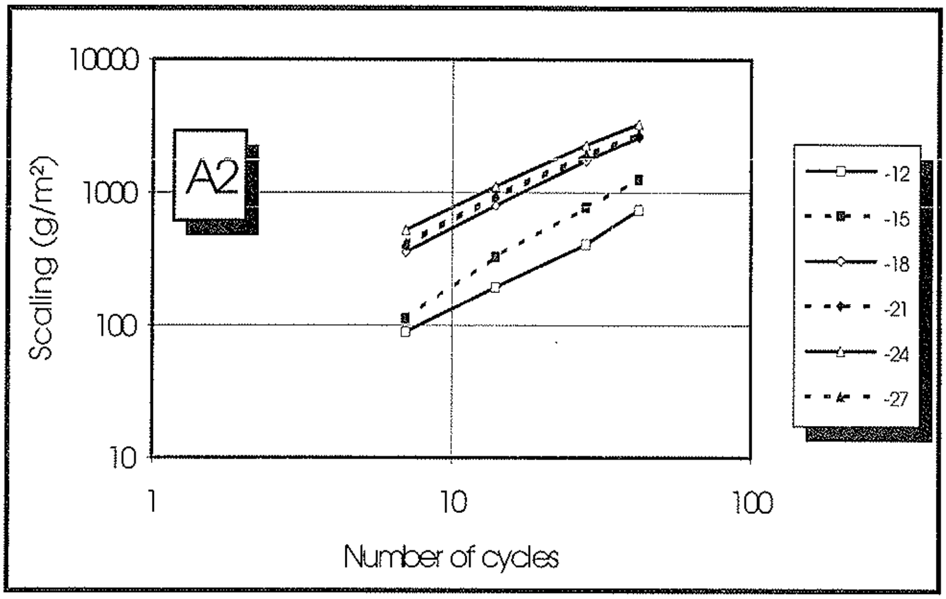


FIGURE 5 Scaling as a function of the number of freeze-thaw cycles for different values of the minimum temperature. The results are relevant for A2 (quality A, sawn surface, no drying before testing).

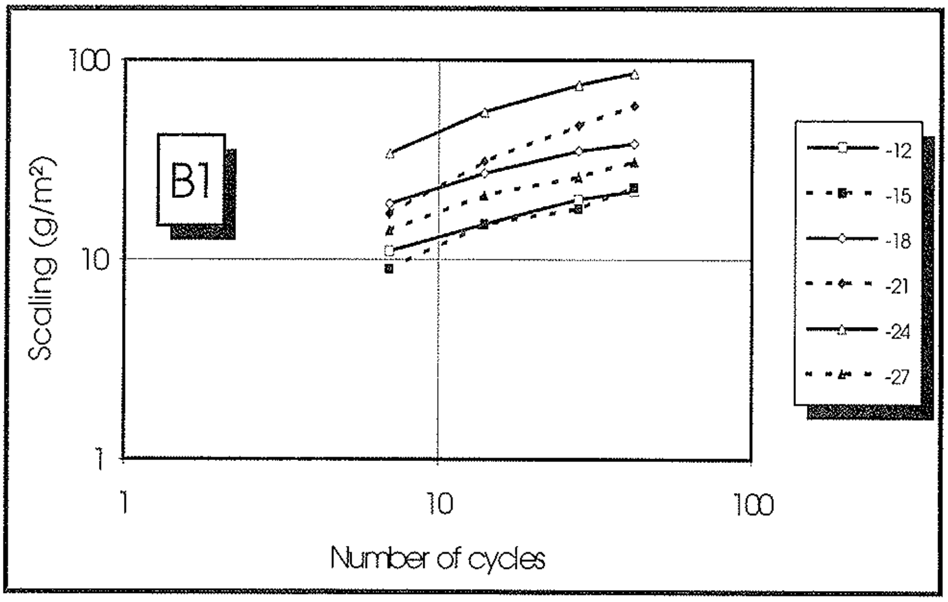


FIGURE 6 Scaling as a function of the number of freeze-thaw cycles for different values of the minimum temperature. The results are relevant for B1 (quality B, sawn surface, dried for 7 days before testing).

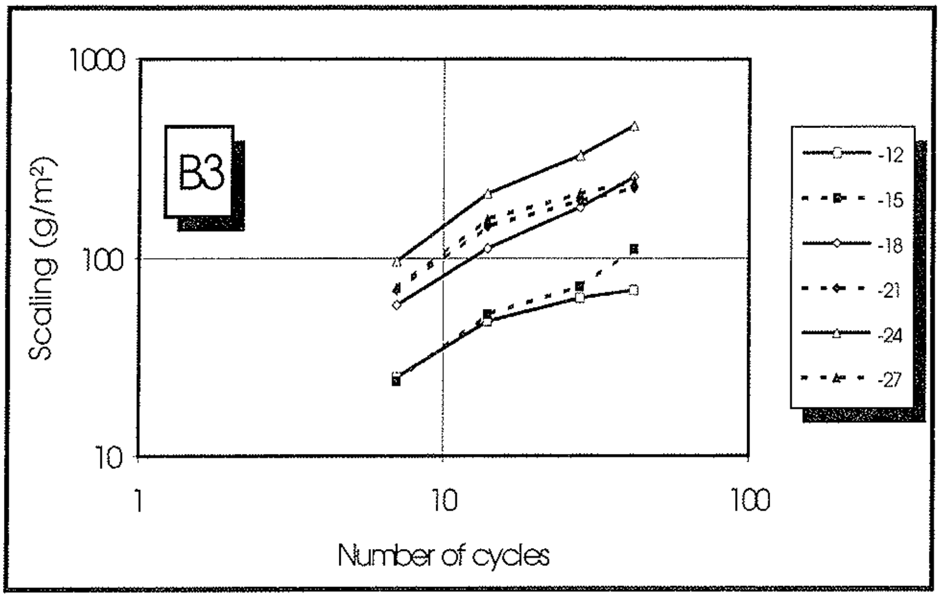


FIGURE 7 Scaling as a function of the number of freeze-thaw cycles for different values of the minimum temperature. The results are relevant for B3 (quality B, surface cast against mould, dried for 7 days before testing).

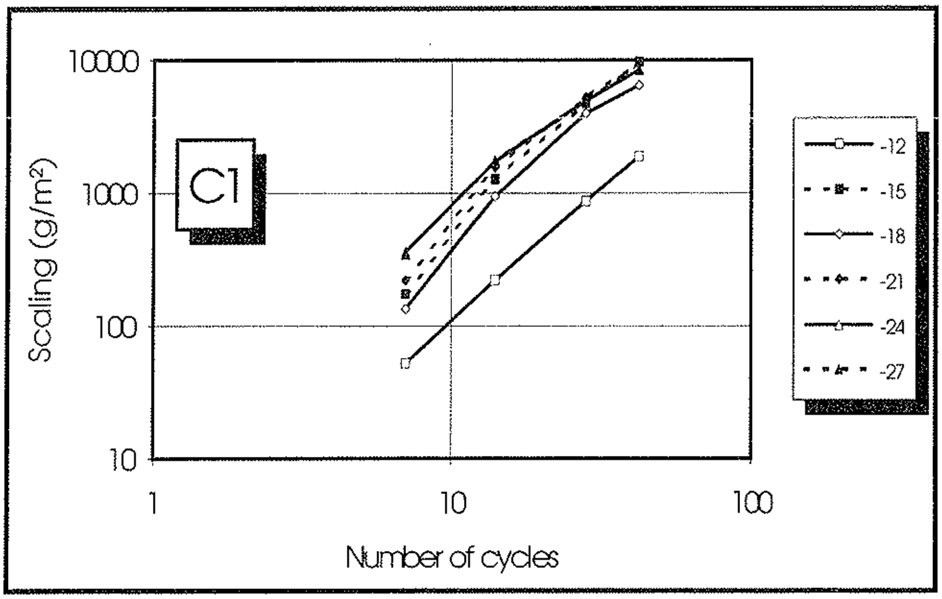


FIGURE 8 Scaling as a function of the number of freeze-thaw cycles for different values of the minimum temperature. The results are relevant for C1 (quality C, sawn surface, dried for 7 days before testing).

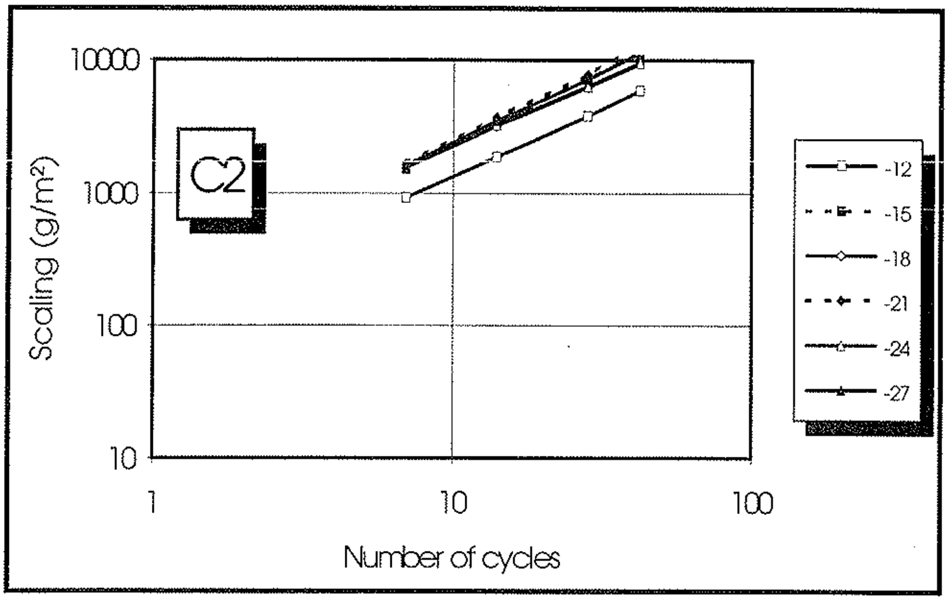


FIGURE 9 Scaling as a function of the number of freeze-thaw cycles for different values of the minimum temperature. The results are relevant for C2 (quality C, sawn surface, no drying before testing).

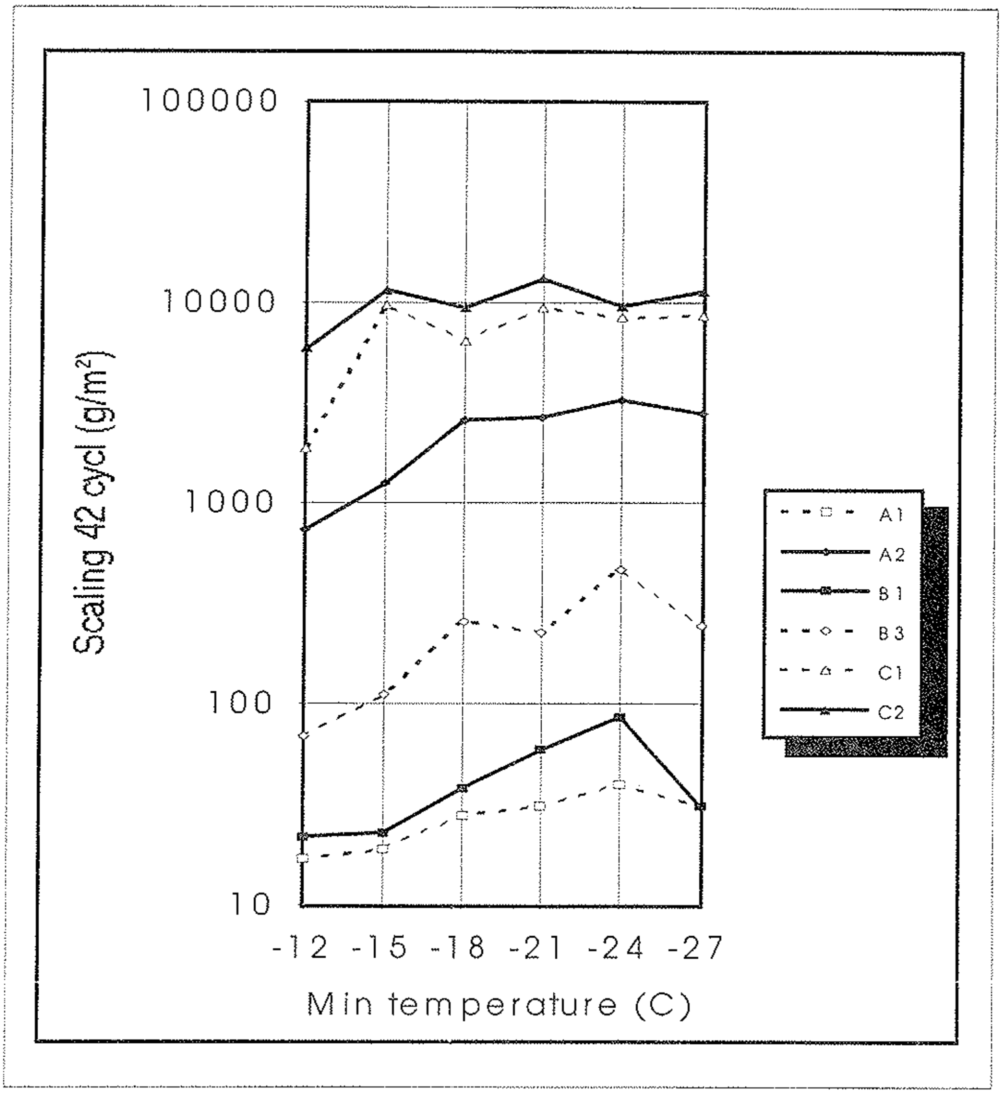


FIGURE 10 Scaling after 42 cycles as functions of the minimum temperature.

5.3 Influence of preconditioning method on the scaling resistance

In this investigation, two preconditioning methods were used. Method 1 was performed according to the standard procedure in SS 13 72 44, i.e. the specimen was dried in a climate chamber (RH=50±5%, temp=20±2°C, wind<0.1m/s) for seven days before the start of the resaturation which started when the concrete was 28 days old. In method 2 there was no drying at all before the start of the test. The specimen was sawn 2 days after casting and then put directly into a plastic bag where it was kept until the start of resaturation.

In figures 11 and 12 the results for the two preconditioning methods are compared. For both qualities A and B the scaling is much higher for preconditioning method 2 (no drying) than for method 1. It can also be seen that the shapes of the curves differ. For method 1 the curves are non-linear, while the scaling is almost perfectly proportional to the number of freeze-thaw cycles for method 2. The reason for this may be that there is a moisture gradient close to the surface when the concrete has been subjected to drying according to method 1. As the scaling is probably strongly dependent on the preconditioning, and thus on the moisture history, this may explain the non-linearity of the curves. When the specimens are kept in plastic bags all the time, there are no moisture gradients and therefore the scaling curves are straight lines.

In figure 13 scaling according to the preconditioning method 1 is plotted against the results for method 2 in a log-log diagram. Especially for low scaling values, method 2 produces much higher scaling than method 1. According to figure 13, however, it seems that, for each value of the number of freeze-thaw cycles, there is a reasonably well defined correlation between the results for the two preconditioning methods. This means that the two preconditioning methods ought to be inter-changeable, at least where Portland cement concrete is concerned. Of course different preconditioning methods must always be matched with different assessment criteria.

There may be some advantages to the preconditioning method 2 (no drying) which produces higher scaling values:

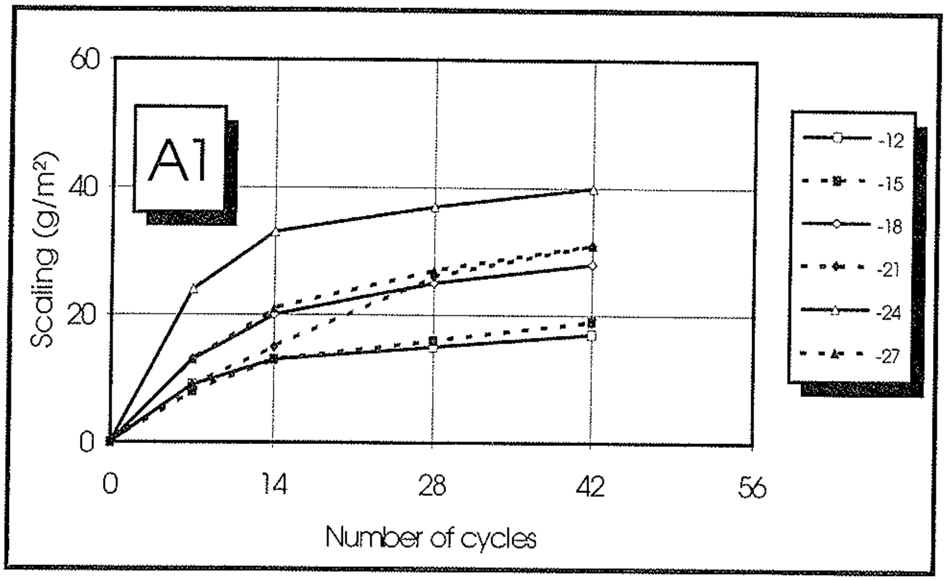
- A higher scaling level normally means that the test results are less dependent on the minimum temperature, see 5.2.

- A higher scaling level normally means lower scatter and better precision of the test results. This is discussed in detail in 5.5.

- Preconditioning method 2 makes the scaling value proportional to the number of freeze-thaw cycles. This may be important for a more rapid evaluation of the test results. A rough estimate of the results of the 56-cycle scaling can be obtained after only a few freeze-thaw cycles.

- It is easy to obtain the correct climate for preconditioning method 2. The only important parameter is temperature. In the standard procedure for preconditioning according to SS 13 72 44 there are three important climate parameters; temperature, relative humidity and wind velocity, and it is often difficult to obtain a correct and stable climate.

A new preconditioning method can only be used if it leads to results that rate concrete in the correct order according to the performance of real outdoor concrete structures. This means that a new preconditioning method must rate concrete in the same way as when the standard preconditioning procedure is used, as the latter has been proven suitable, according to results based on long experience.



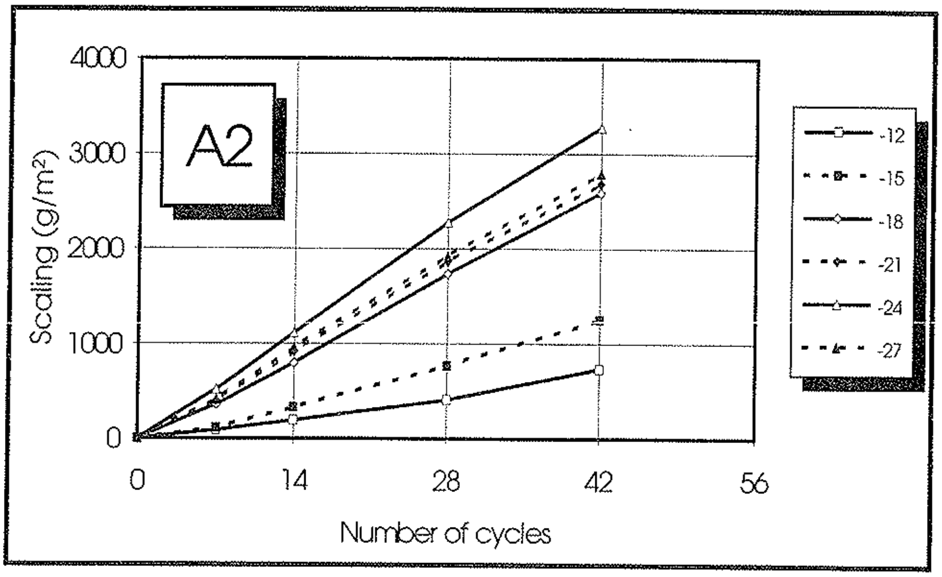


FIGURE 11 Scaling for concrete quality A as a function of the number of freeze-thaw cycles for different minimum temperatures. The results are relevant for preconditioning method 1 (top) and method 2 (bottom). It can be observed that the scales for the vertical axes are different for the two diagrams.

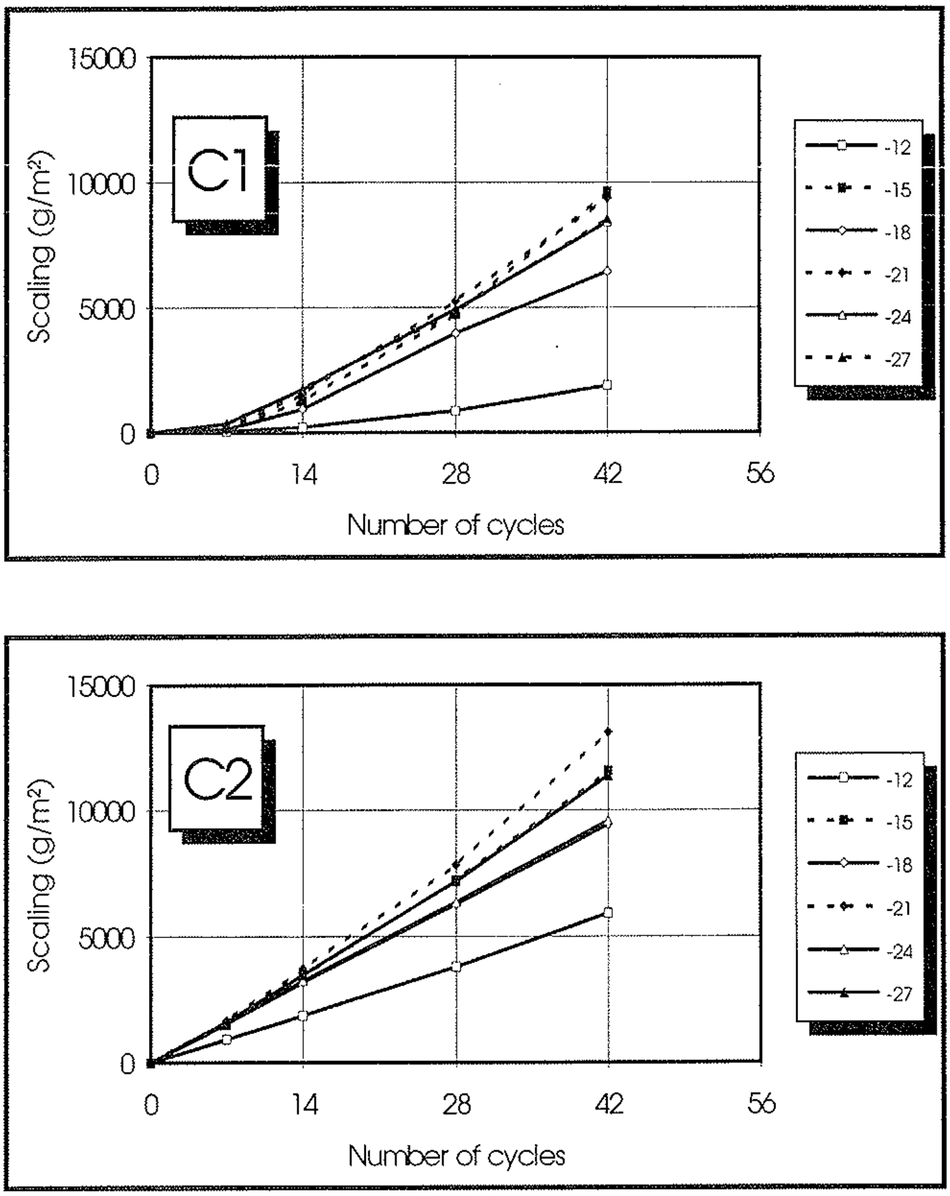


FIGURE 12 Scaling for concrete quality C as a function of the number of freeze-thaw cycles for different minimum temperatures. The results are relevant for preconditioning method 1 (top) and method 2 (bottom).

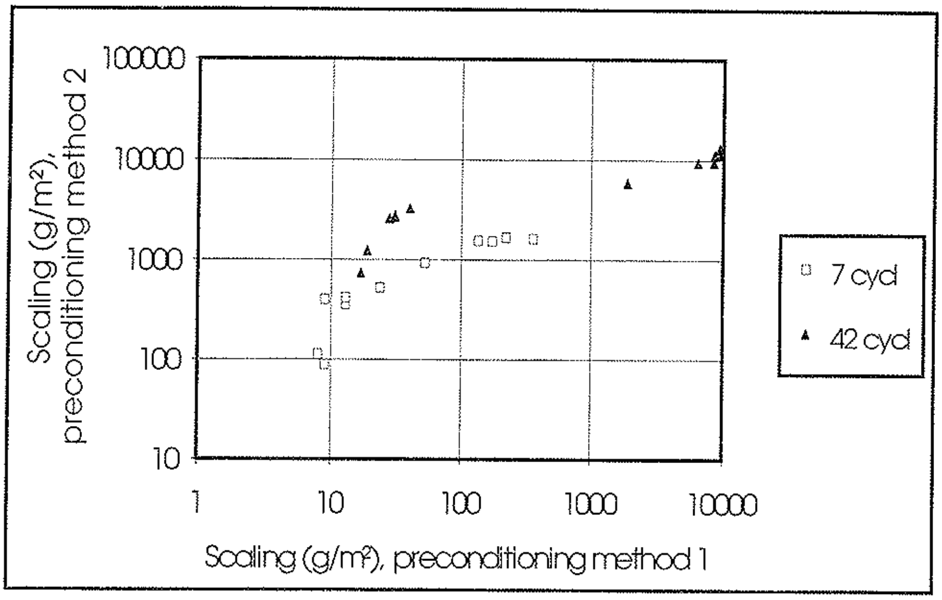
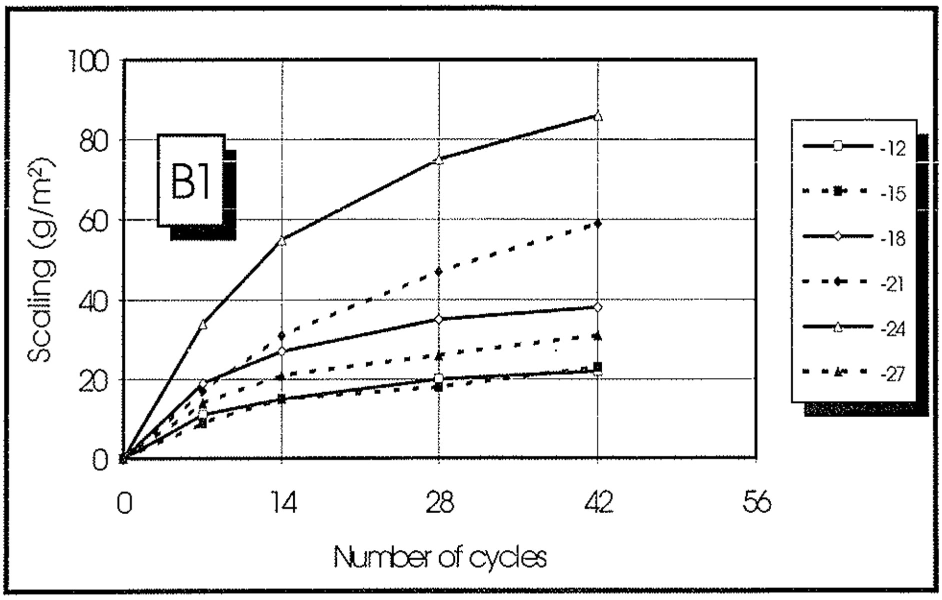


FIGURE 13 Scaling according to preconditioning method 2 (no drying) as functions of scaling according to method 1 (drying 7 days before testing). The results represent the concrete qualities A and C.

5.4 Influence of type of test surface

Two different types of test surfaces were used in this investigation; sawn or cast against the inside of a steel mould. A very thin layer of demoulding agent was used to make it possible to demould the cubes without damage the surfaces. The sawn surface was dried for 7 days in the climate chamber before testing, while the corresponding figure for the surface cast against the mould was 21 days.

The results for the two types of surfaces are compared in figure 14. According to the test results the scaling is lower for the sawn surface than for the surface cast against the mould. It is not possible to explain this difference from the results in this investigation. There are, however, two probable explanations. The first is that the percentage of paste in the sawn surface is only about 30 to 40% of that with the surface cast against the mould. The other is that the preconditioning is different and that the concrete properties are different close to the surface as compared with the interior of the cube.



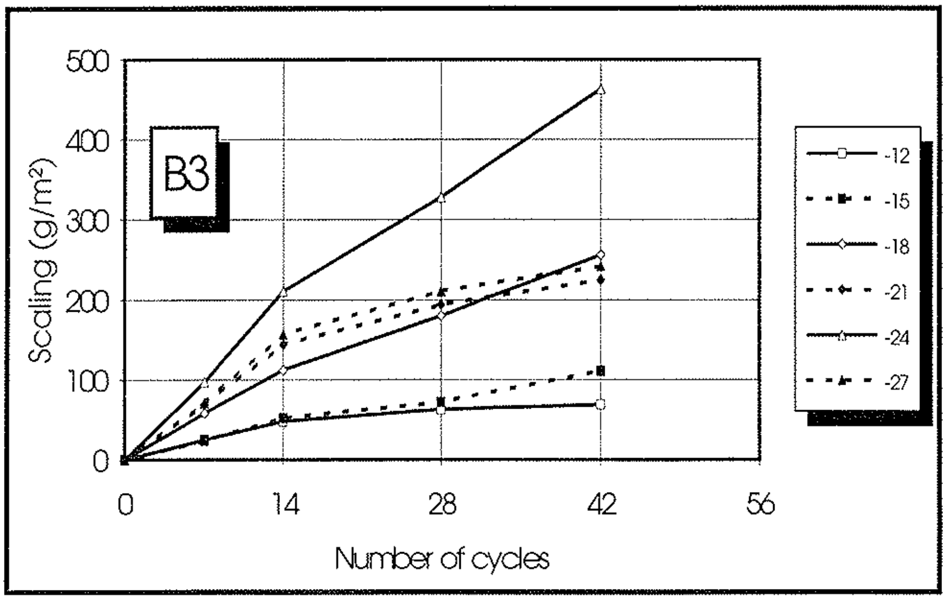


FIGURE 14 Scaling for concrete quality B as a function of the number of freeze-thaw cycles for different minimum temperatures. The results are relevant for a sawn surface (top) and a surface cast against a steel mould (bottom). It can be observed that the scales for the vertical axes are different for the two diagrams.

In figure 15, the results for the two different surfaces are compared. There seems to be a rather good correlation between the test results. The results are, however, primarily relevant for the concrete tested in this investigation. Other concrete qualities and other binders may give rise to different results.

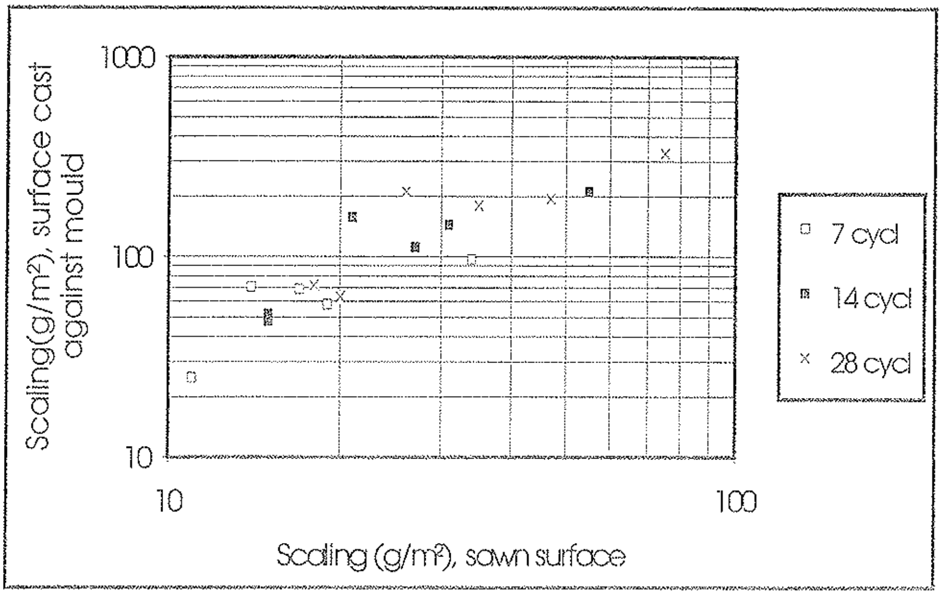


FIGURE 15 Scaling for a surface cast against a steel mould as function of scaling for a sawn surface. The results represent concrete quality B.

5.5 Precision of the test results

In figure 16, the coefficient of variation (cov) is plotted against the scaling value after 28 cycles. Each value represents four specimens.

The cov is rather high, but it decreases as the scaling increases. The cov is markedly higher for high minimum temperatures, and in figure 17 cov values for minimum temperatures above -18°C are excluded. According to figure 17 the coefficient of variation is about 10% for scaling values exceeding about 1000 g/m^2 but higher for low scaling values. This means that the precision of the test method can normally be assumed to be good enough, at least for the critical value 1 kg/m^2, which is often used as a limit for acceptable scaling resistance.

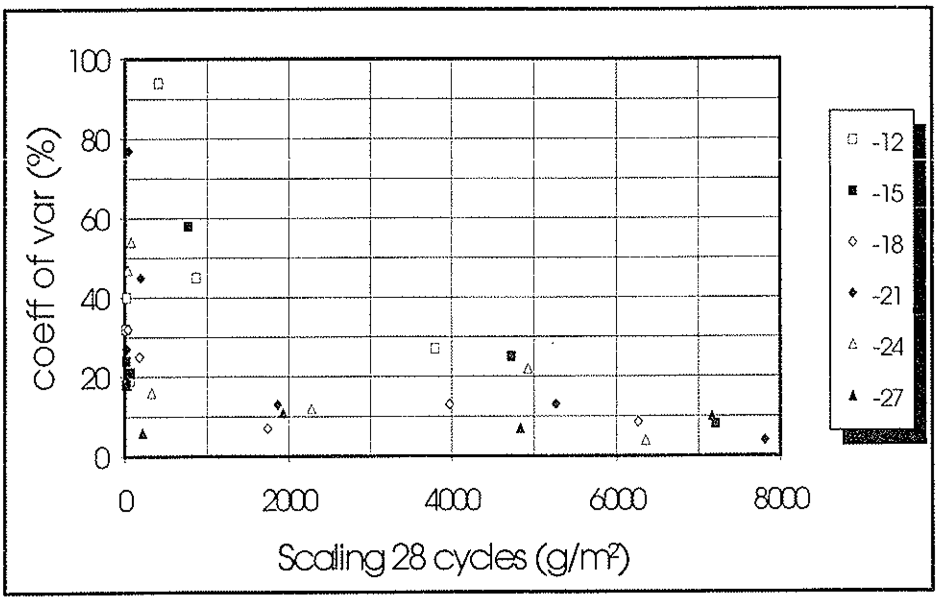


FIGURE 16 Coefficient of variation as a function of scaling after 28 cycles. The figure is relevant for minimum temperatures between -12 and -27°C.

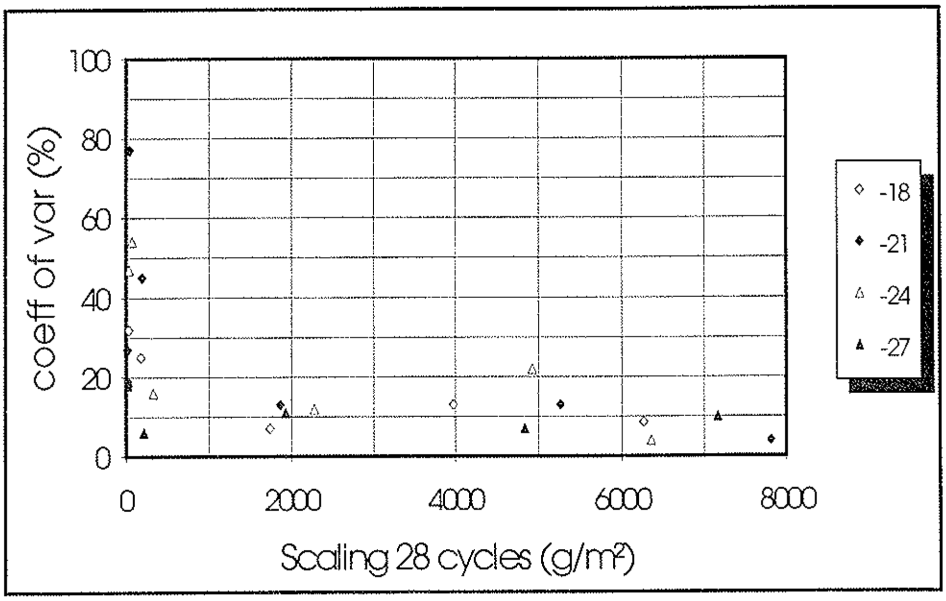


FIGURE 17 Coefficient of variation as a function of scaling after 28 cycles. The figure is relevant for minimum temperatures between -18 and -27°C.

6 Conclusions

The results of this investigation make it possible to draw the following conclusions. All the tests were performed on concrete with Portland cement as binder and the conclusions are therefore relevant only for this type of concrete quality. Other binders and concrete compositions may give rise to different results.

- The minimum temperature of the freeze-thaw cycle influences the scaling resistance of concrete when tested according to the Scandinavian slab method, SS 13 72 44. Lower minimum temperatures normally result in more severe scaling. The influence is most pronounced for low scaling values and high minimum temperatures. When the scaling exceeds 100-1000 g/m² and the minimum temperature is about -18°C or lower, the influence of the minimum temperature appears to be negligible.

- The precision of the test results is improved with increasing values of the scaling. For scaling values exceeding 500-1000 g/m² the coefficient of variation, under repeatable conditions, seems to be about 10%.

- The method of preconditioning the specimens strongly influences the test results. Scaling is much less severe when the specimens are allowed to dry for a week before the start of the freeze-thaw test than when the specimens are kept in a plastic bag, which prevents evaporation from the specimen, all the time until the start of testing. The difference is most pronounced for low scaling values. Another observation is that the scaling seems to be proportional to the number of freeze-thaw cycles for the specimens kept in the plastic bags but not for the specimens which were dried for seven days before testing .

- Scaling seems to be more severe for surfaces cast against the inside of steel moulds than for sawn surfaces. This conclusion is uncertain, however, as it is based on tests of only a single concrete quality.

7 References

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Appendix 1

TABLE. Composition of the cement used for all the concrete mixes

	Degerhamn anl
Component	**% by weight**
SiO_2	22.6
TiO_2	0.20
Fe_2O_3	4.29
Al_2O_3	3.41
MnO	0.22
CaO	66.3
MgO	1.19
Na_2O	0.13
K_2O	0.70
SO_3	2.4
C_3S	62.4
C_2S	17.7
C_3A	1.8
C_4AF	13.1
Heat of hydr (7 days)	260 kJ/kg

Appendix 2. Individual test results

Quality	Precond	Surface	min.temp (°C)	Speci- men	Scaling (g/m²) 7c	14c	28c	42c
A	1	Sawn	-12	A1	12	17	20	22
				A2	11	15	18	20
				A3	8	10	12	14
				A4	5	8	9	11
			-15	A34	9	15	18	21
				A35	4	8	12	16
				A36	9	15	17	19
				A37	10	14	17	21
			-18	A10	15	22	26	28
				A11	9	15	19	22
				A13	10	18	25	27
				A14	19	24	31	33
			-21	A43	11	19	32	39
				A44	9	14	27	32
				A46	8	14	29	32
				A47	7	12	16	20
			-24	A49	18	23	27	29
				A20	24	34	38	42
				A22	14	19	22	27
				A23	39	55	61	64
			-27	A52	10	18	30	36
				A53	19	27	32	37
				A55	10	16	20	23
				A56	11	23	26	30
A	2	Sawn	-12	A3	60	72	87	334
				A6	87	110	169	481
				A7	47	165	438	728
				A9	162	426	938	1407
			-15	A36	159	456	1132	1861
				A39	67	93	134	205
				A40	85	318	780	1310
				A42	141	447	1033	1630
			-18	A12	288	655	1610	2567
				A15	412	881	1704	2396
				A16	364	876	1895	2768
				A18	365	779	1730	2624
			-21	A45	460	1048	2088	2948
				A48	329	715	1538	2275
				A49	377	935	1869	2696
				A51	420	973	1968	2816
			-24	A21	643	1296	2467	3371
				A24	376	907	2087	3190
				A25	638	1339	2555	3542
				A27	430	913	2005	2994

Quality	Precond	Surface	min.temp (°C)	Speci-men	Scaling (g/m²) 7c	14c	28c	42c
A	2	Sawn	-27	A54	376	870	1760	2544
				A57	368	842	1744	2532
				A58	460	1073	2134	3028
				A60	459	1058	2085	3059
B	1	Sawn	-12	B1	16	24	28	30
				B2	8	10	12	15
				B4	11	16	20	22
				B5	8	11	16	19
			-15	B34	7	12	17	22
				B35	9	16	19	23
				B37	7	12	13	17
				B38	13	20	24	28
			-18	B10	24	34	38	41
				B11	27	40	48	52
				B13	12	17	21	23
				B14	11	18	32	37
			-21	B43	14	22	26	30
				B44	27	53	98	124
				B46	18	32	45	52
				B47	10	15	19	31
			-24	B19	57	90	131	158
				B20	15	26	36	41
				B22	25	42	56	63
				B23	40	60	78	84
			-27	B52	10	17	21	24
				B53	14	21	27	33
				B55	13	20	24	28
				B56	18	26	32	38
B	3	Cast surf	-12	B3	17	40	58	66
				B6	29	54	71	78
				B7	20	36	48	52
				B9	32	62	75	79
			-15	B36	16	46	57	63
				B39	33	68	75	84
				B40	22	48	92	222
				B42	23	44	64	74
			-18	B12	51	100	232	398
				B15	78	144	200	253
				B16	45	91	141	200
				B18	56	113	145	173
			-21	B45	89	198	320	411
				B48	73	131	155	164
				B49	48	99	124	131
				B51	67	148	180	192

			min.temp	Speci-	Scaling	(g/m²)		
Quality	Precond	Surface	(°C)	men	7c	14c	28c	42c
B	3	Cast surf	-24	B21	172	290	365	419
				B24	100	213	335	471
				B25	68	174	251	320
				B27	48	166	364	640
			-27	B54	76	173	216	226
				B57	47	123	208	280
				B58	88	186	226	240
				B60	71	144	195	223
C	1	Sawn	-12	C1	62	206	586	1279
				C2	15	79	480	1288
				C4	80	332	1168	2225
				C5	52	261	1239	2752
			-15	C34	124	1348	5780	11462
				C35	240	1605	4885	10499
				C37	248	1564	5190	9367
				C38	80	575	3073	7196
			-18	C10	138	1036	4000	(5813)
				C11	76	631	3248	6020
				C13	220	1339	4160	7745
				C14	102	775	4493	(6228)
			-21	C43	113	1324	5352	11378
				C44	204	1598	5264	9274
				C46	386	2017	6024	10588
				C47	177	1280	4414	8280
			-24	C19	684	2293	5703	8365
				C20	114	1003	3618	6420
				C22	417	2134	5923	10606
				C23	218	1525	4458	8351
			-27	C52	211	1692	5057	7229
				C53	266	1601	4735	6140
				C55	418	1784	4389	7776
				C56	481	1968	5166	7522
C	2	Sawn	-12	C3	573	1212	2600	4436
				C6	1047	2164	4205	6406
				C7	964	1855	3400	5280
				C9	1132	2277	4988	7515
			-15	C36	1581	3854	7881	12612
				C39	1569	3158	6889	10392
				C40	1520	3492	7526	12305
				C42	1464	3195	6742	10897
			-18	C12	1587	3399	6864	10511
				C15	1569	3312	6394	9226
				C16	1577	3097	6220	9608
				C18	1502	2993	5572	8331

			min.temp	Speci-	Scaling (g/m²)			
Quality	Precond	Surface	(°C)	men	7c	14c	28c	42c
C	2	Sawn	-21	C45	1407	3416	7442	12181
				C48	1805	3972	8155	12394
				C49	1842	3926	7860	13628
				C51	1671	3601	7791	14244
			-24	C21	1619	3256	6241	9063
				C24	1524	3138	6275	9817
				C25	1817	3594	6713	9961
				C27	1573	3064	6192	9468
			-27	C54	1503	3352	7229	11416
				C57	1586	3251	6140	9443
				C58	1732	3852	7776	13205
				C60	1674	3520	7522	11429

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