LEACHING PROPERTIES OF SELF COMPACTING CONCRETE (SCC)

ELUTIONSVERHALTEN VON SELBSTVERDICHTENDEM BETON (SVB)

COMPORTEMENT D'ELUTION DU BETON AUTOCOMPACTANT (BAC)

Uwe Herterich, Gerhard Volland, Timo Wüstholz, Michael Stegmaier

SUMMARY

In order to obtain the characteristic properties of self compacting concrete (SCC) highly effective water reducing agents (superplasticizers) based on polycarboxylate esters (PCE) are necessary. Compared to conventional concrete higher concentrations of superplasticizer (1-2 % relative to cement) are added.

The determination of mobile organic compounds of PCE-plasticizers in leachates of monolithic SCC-bodies with various w/c ratios (w/c from 0.34 to 0.70) by nuclear magnetic resonance spectroscopy (^{1}H NMR) and total organic carbon (TOC) shows that only small ratios of originally added PCE are mobile via ground water. Even under ″worst case″ conditions (concrete bodies aged for 3 days and deionized water as leachate) less than 2 % of the total PCE are mobile within 56 days. Though their plasticizer concentrations are higher, SCC concretes with lower w/c-ratios (e.g. M85 w/c-ratio 0.34 and plasticizer concentration up to 1.5% relative to cement) lead to significant smaller amounts of leached organic compounds (less than 0.5 % of added PCE). Thus the present investigations give hints that the mobility of soluble PCE components (long-chain polyalcohols) is reduced in concrete with smaller pore radii.

The investigation also shows that transport processes for most of the leached organic compounds are controlled by diffusion processes. For larger organic molecules like long-chain polyalcohols (e.g. polyethylene glycol) as soluble part of admixtures based on PCE combined with concrete with small pore radii pronounced deviations are detectable. After an initial wash-off of surface

bound amounts almost no further emission of those soluble compounds (polyalcohols) can be detected.

This combination of properties of concretes and admixtures leads to types of concrete which can be regarded as suitable concerning environmental compatibility.

ZUSAMMENFASSUNG

Zur Herstellung von selbstverdichtendem Beton (SVB), werden hochwirksame Fließmittel auf der Basis von Polycarboxylatethern (PCE) in relativ hoher Dosierung (1-2 % bezogen auf den Zementgehalt) der Frischbetonmischung zugegeben.

Die Bestimmung der mobilen organischen Anteile von PCE-Fließmitteln in den Eluaten monolithischer SVB-Probekörper mit unterschiedlichen w/z-Werten ($0{,}34 \leq w/z \leq 0{,}7$) mittels Kernresonanzspektroskopie (^{1}H NMR) bzw. durch Bestimmung des gesamten organischen Kohlenstoffs (TOC) zeigt, dass nur kleine Bruchteile des ursprünglich zugegebenen PCEs über den Grundwasserpfad mobilisierbar sind. Selbst unter "worst case" Bedingungen (3 Tage alte Betonproben und vollentsalztes Wasser als Elutionsmittel) sind weniger als 2 % des gesamten PCEs innerhalb von 56 Tagen mobilisierbar. SVB-Typen mit niedrigem w/z-Wert (z.B. M85 w/z-Wert = 0,85, Fließmittelgehalt bis zu 1,5 % bezogen auf Zement) weisen trotz ihres höheren Fließmittelgehalts deutlich kleinere eluierte Mengen an organischen Verbindungen auf (weniger als 0,5 % des zugegebenen PCEs). Damit deuten die vorliegenden Untersuchungen darauf hin, dass die Mobilität der löslichen Anteile des PCEs (langkettige Polyalkolhole) in Betonen mit kleinen Porenradien deutlich reduziert ist.

Die Untersuchungen zeigen auch, dass für die meisten eluierten organischen Verbindungen die Diffusion den dominierenden Transportprozess darstellt. Bei größeren organischen Molekülen wie langkettigen Polyalkoholen (z.B. Polyethylenglykol) als löslicher Anteil der Wirkstoffe auf PCE-Basis und Betonen mit kleinen Porengrößen werden deutliche Abweichungen von der Diffusion beobachtet. So werden nach Anfangsauswaschung der an der Oberfläche haftenden Stoffmengen in den nachfolgenden Elutionsschritten nur noch geringe Mengen der löslichen Komponente des Wirkstoffs eluiert.

Diese Kombination von Eigenschaften von Betonen und Zusatzmitteln führt zu Betonen, die unter dem Gesichtspunkt der Umweltverträglichkeit als besonders problemlos einzustufen sind.

RESUMÉ

Pour la production du béton autocompactant on utilise des adjuvants plastifiçants à la base du éther polycarboxulant (PCE) avec un dosage prèsque haut (1 à 2 % rel. au content du ciment). Seulement un petit part du dosage est mobilisable si la spectroscopie de résonance magnétique nucléaire montre. Les recherches ont montré aussi que la diffusion est le procédé décisif. En cas des molecules à longue chaine il y a une difference. La combinaison du béton et des adjuvants cause un grand caractère consiliant en ce qui concerne l`environnement.

KEYWORDS: self compacting concrete, porosity, NMR, TOC, leaching, environmental risks

1. INTRODUCTION

Self compacting concrete (SCC) was developed in the middle of the 1980's in Japan. SCC flows under its own weight, deaerates and consolidates without adding any additional energy and is resistant to segregation. These characteristics were made possible by the development of highly effective water reducing agents (superplasticizers), usually based on polycarboxylate esters (PCE) (fig.1).

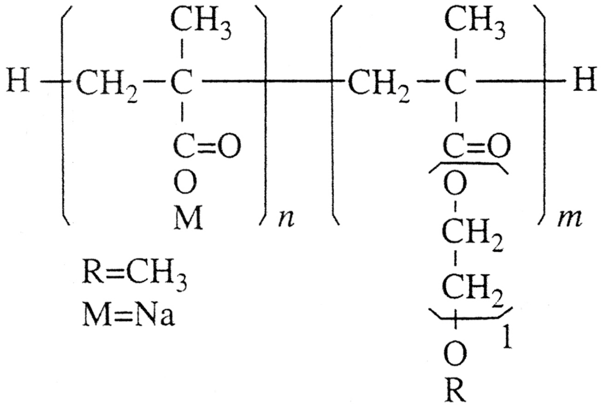


Fig. 1: Polycarboxylate ester (PCE): copolymer of methacrylic acid and methacrylic acid esterified with polyethylene glycol methylether.

These superplasticizers consist of a polymethacrylic acid backbone which is partially esterified with polyethylene glycol methylether sidechains. Upon contact with cement there is saponification of the PCE. Of the two resulting parts – polymethacrylic acid backbone and free polyethylene glycol(derivative) – only polyethylene glycol(derivative) is mobile in aqueous solutions [1].

The added superplasticizers are not considered as biologically easily degradable and may not directly discharged in discharge systems, ground- and surface water [2].

The presented investigation serves to quantify mobile substances leached out of monolithic SCC bodies in contact with water as was done for conventional concrete containing naphthaline sulfonate as concrete admixture by other authors [3,4,5]. For the investigations ″worst case″ conditions were chosen. The obtained results can thus be regarded as maximum values for leaching monolithic SCC bodies in contact with ground water.

2. INVESTIGATIONS

2.1 Investigated concrete mixtures

Cylindrical shaped monolythic bodies of SCC were investigated. Leaching experiments were performed on powder type SCC's M25 and M85 (strength classes C30/37 and C60/75, respectively) and on the viscosity agent type SCC S25 (strength class C30/37). Technical parameters of the concretes are as follows:

M25: w/c = 0.7, content of superplasticizer: 1.25% by mass of cement

M85: w/c = 0.34, content of superplasticizer: 1.45% by mass of cement

S25: w/c = 0.65, content of superplasticizer: 1.5%. by mass of cement.

Samples were hardened at 20°C for 3 days in closed beakers out of polyethylene. For comparison reasons additionally SCC type M25 without admixtures (and thus not self compacting) was investigated as a reference sample.

The detailed composition of the concretes investigated are shown in table 1.

Table 1: Composition of the investigated concretes

	M25	**S25**	**M85**
Cement	CEM II/A-LL32.5R	CEM II/A-LL32.5R	CEM II/A-LL42.5R
cement content [kg/m³]	240	247	500
water content [kg/m³]	168	160	183
lime stone powder [kg/m³]	338	149	0
fly ash [kg/m³]	0	0	137
sand 0/4 mm [kg/m³]	752	833	705
gravel 4/16 mm [kg/m³]	856	959	819
powder content [kg/m³]	594	416	648
superplasticizer [% by mass of cement]	1.25	1.50	1.45
viscosity agent [% by mass of cement]	0.00	0.45	0.00
$(w/c)_{eq}$ [-]	0.70	0.65	0.34

The manufactured concrete mixes were tested on their rheological behaviour directly after mixing. Table 2 shows the results of these tests.

Table 2: Rheological behaviour of the investigated concretes

	M25	**S25**	**M85**
v-funnel time [s]	11.0	5.0	12.0
slump flow [mm]	780	720	770
t_{500} [s]	6.0	4.0	8.0
slump flow with J-ring [mm]	785	685	730

2.1.1 Investigation of the pore size distribution of the concrete mixes

Prior to the start of the leaching experiments at the concrete age of 3d the pore size distribution of the concretes was investigated by means of the mercury intrusion porosimetry. Therefore parts of the specimens were dried in an oven at 105 °C until there was no further change in mass.

2.1.2 Investigation of the compressive strength of the concretes

The compressive strength of the SCC’s was investigated at the age of 3d and 28d of the mixes. Therefore cubes with an edge length of 150 mm were cast. The specimens for the test at an age of 3d were stored constantly at 20 °C and 100 % r.h.. The cubes for the test at an age of 28d were stored for 7d at 20 °C and 100 % r.h. and 21d at 20 °C and 65 % r.h..

The compressive strength of the SCC’s at an age of 56d was not measured experimentally. But it is possible to calculate this strength with the following formula [6]:

$$f_{cm,56} = f_{cm,28} \cdot \exp\left\{ s\left(1 - \left(\tfrac{28}{56}\right)^{1/2}\right)\right\} \tag{1}$$

with:

$f_{cm,56}$ = mean compressive strength at 56d [N/mm²]

$f_{cm,28}$ = mean compressive strength at 28d [N/mm²]

s = 0.25 for CEM 32.5R

0.20 for CEM 42.5R

2.2 Leaching experiments

Deionized water with its higher dissolving power compared to ground water was chosen as medium for leaching. This was done on the one hand to determine an upper limit for possible emissions and on the other hand because of the good reproducibility and the extremly low TOC concentration of deionized water compared to ground water with its diverse consistency.

The eluent was renewed in specified time intervals, to avoid saturation of the analytes and to maintain a high gradient of concentration between concrete matrix and eluent. Time intervals for renewal of eluent were defined according to a modified Standtest Arbeitsprogramm DAfStb [7]: after 1, 3, 7, 16, 32 and 56 days, respectively.

2.3 Investigations of leachates

2.3.1 Determination of TOC emissions

Of the 6 leaching steps conducted, for leaching steps No. 1, 3 and 5 the TOC concentrations of the leachates were determined for all of the four investigated SCC bodies.

2.3.2 ^{1}H NMR investigation of aqueous leachates

Contrary to TOC as a sum parameter for all organic components ^{1}H NMR measurements of the leachates No. 1-6 allow the identification and quantification of the individual organic compounds.

3. RESULTS

3.1 Pore size distribution

The results of the pore size distribution investigated by mercury intrusion porosimetry are shown in the following figures.

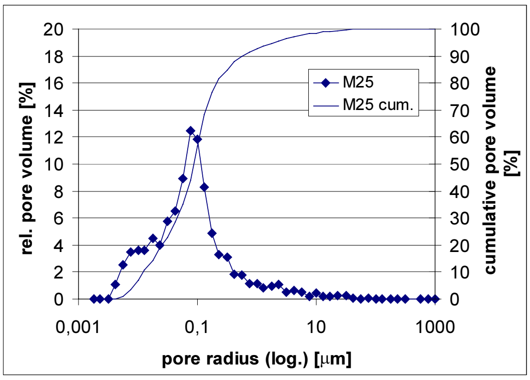


Fig. 2a: Pore size distribution of M25

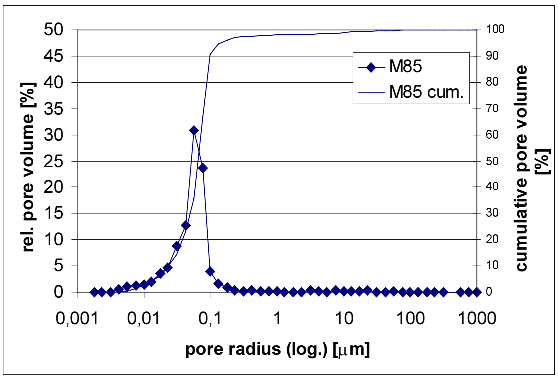


Fig. 2b: Pore size distribution of M85

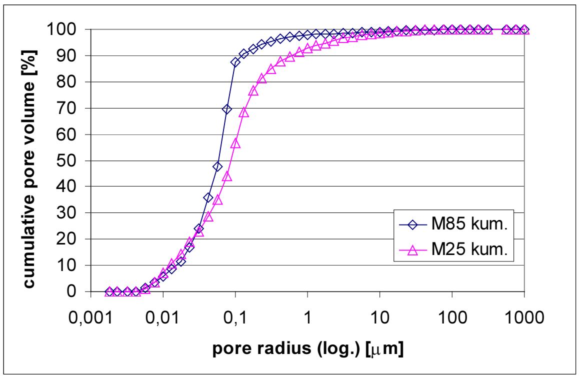


Fig. 2c: comparison of the cumulative pore volume of the tested SCC's

As can be seen in fig. 2c there is a difference in the pore size distribution of M25 and M85. The high strength concrete M85 contains more smaller pores than the normal strength concrete M25. This can be explained by the difference in the $(w/c)_{eq}$-ratio. There is also a difference in total porosity of these two concretes. M25 has a total porosity of 15,6 Vol.-% and M85 of 13,5 Vol.-% (values also obtained by mercury intrusion porosimetry). This difference in total porosity can also influence the leaching behaviour of the individual concretes.

The varying of pore size distribution and total porosity should have an influence on the leaching behaviour of the SCC's.

3.2 Strength development of the SCC's

The measured and calculated compressive strengths of the three SCC's are shown in table 3. As mentioned before, the values at 3d and 28d are measured compressive strengths while the compressive strength at 56d was calculated by using formula (1) [6].

Table 3: compressive strength of the SCC's at different ages

	compressive strength [MPa]		
	3 d	28 d	56 d
M25	25.2	40.2	43.3
M85	57.3	78.2	82.9

3.3 TOC emissions

Fig. 3 shows TOC emissions of the 4 SCC bodies investigated for leaching steps No. 1, 3 and 5, respectively. In the first leaching step emissions are about twice in magnitude than in successive steps due to the effect of initial wash-off (see below). A comparison of the different samples gives similar TOC ratios for all leaching steps. In total TOC emissions decrease in the following order:

M25 > S25 >> M85 ≈ M25 without admixtures

i.e. sample M85 with the largest added amount of admixtures gives the lowest TOC emissions.

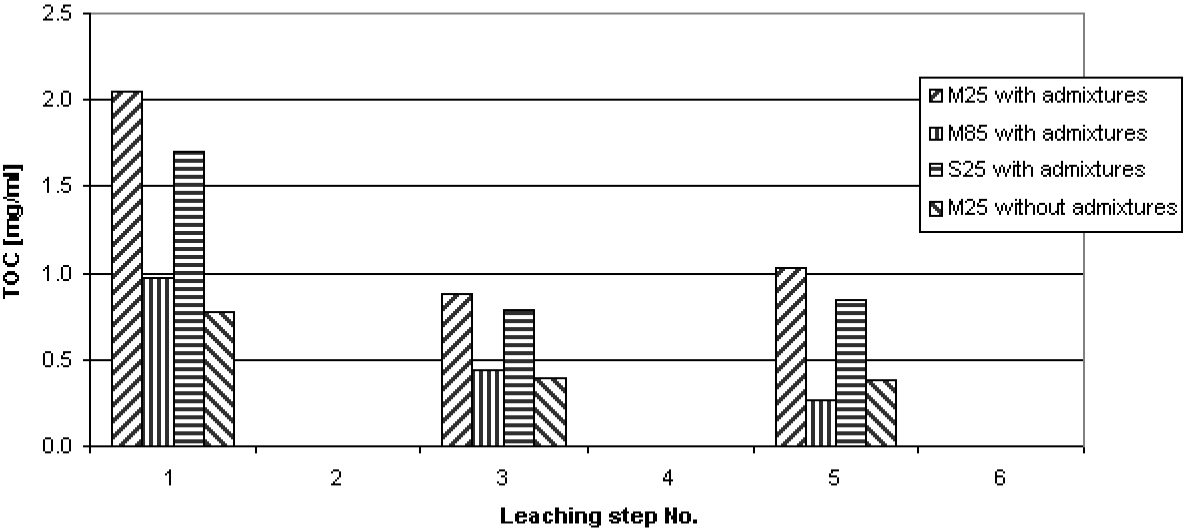


Fig. 3: TOC emissions of leaching steps No. 1,3 and 5 (TOC concentrations are referred to a volume of eluent = 8× surface of sample [cm^3] i.e. V/S = 8:1 as described in [7])

For sample M85 the rapid decrease of the TOC emissions in the course of time is striking. So for leaching step No. 5 TOC emission of M85 is already below that of the reference sample M25 without admixtures whereas in preceding leaching steps M85 gave larger TOC emissions than M25.

A comparison of sample M25 and the reference sample M25 without admixtures shows that about 60% of the TOC emission is due to concrete admixtures.

According to the current stage of discussion on the evaluation of substances hazardous to ground water in Germany, TOC (and DOC) emissions > 20 mg/l measured in a static test after 24 h have to be investigated in more detail. The TOC concentrations of 1-2 mg/l here obtained after 24 h are thus about 1/10 of the presently discussed tolerable TOC in leachates i.e. risks for ground water being in contact with SCC are low.

3.4 ^{1}H NMR investigation

3.4.1 Qualitative evaluation of ^{1}H NMR spectra of leachates

In leachates of SCC bodies with admixtures the soluble part of the active component polyethylene glycol(derivative) and the processing agent p-toluenesulfonic acid as main components of the applied superplasticizer are identified. For SCC sample S25 of the viscosity agent type additionally components of the viscosity agent (naphthaline sulfonate(derivative), crotonate, 3-hydroxybutyrate, isopropanol) are determined. So besides the proof of the superplasticizer the proof of the viscosity agent in a given concrete body is possible as well.

Furthermore compounds independent of admixtures can be identified: besides the ubiquitous compounds acetate, formiate and lactate ethanolamines (particularly triethanolamine applied as a processing agent in the milling of cement) and mineral oil hydrocarbons are found.

For the four SCC bodies investigated the individual components of the leachates identified by ^{1}H NMR are listed in table 4. For a given SCC sample the same species are identified for all leaching steps – there are only differences in the respective amounts quantified.

Table 4: Identified components of leachates of 4 different SCC mixtures – results according to nuclear magnetic resonance spectroscopy (^{1}H NMR); +: detected, -: not detectable

		M25	**M85**	**S25**	**M25 without admixtures**
Components of superplasticizer	Polyethylene glycol (derivative)	+	+	+	-
	Polycarboxylate Backbone	-	-	-	-
	p-Toluenesulfonic acid	+	+	+	-
Components of viscosity agent	Naphthaline sulfonate (derivative)	-	-	+	-
	Crotonate	-	-	+	-
	3-Hydroxybutyrate	-	-	+	-
Components independent of admixtures	Ethanolamines	+	-	+	+

3.4.2 Quantitative evaluation of ^{1}H NMR spectra of leachates

For ^{1}H NMR intensity of signals is directly proportional to the concentration of the corresponding protons. For this reason besides the above qualitative statements quantitative conclusions can be drawn.

Figures 4 a-d display leached amounts of (a) soluble part of active component (corresponding to 93% of the residue after drying of the initial product) (b) p-toluenesulfonic acid and (c) formiate for leaching steps 1-6.

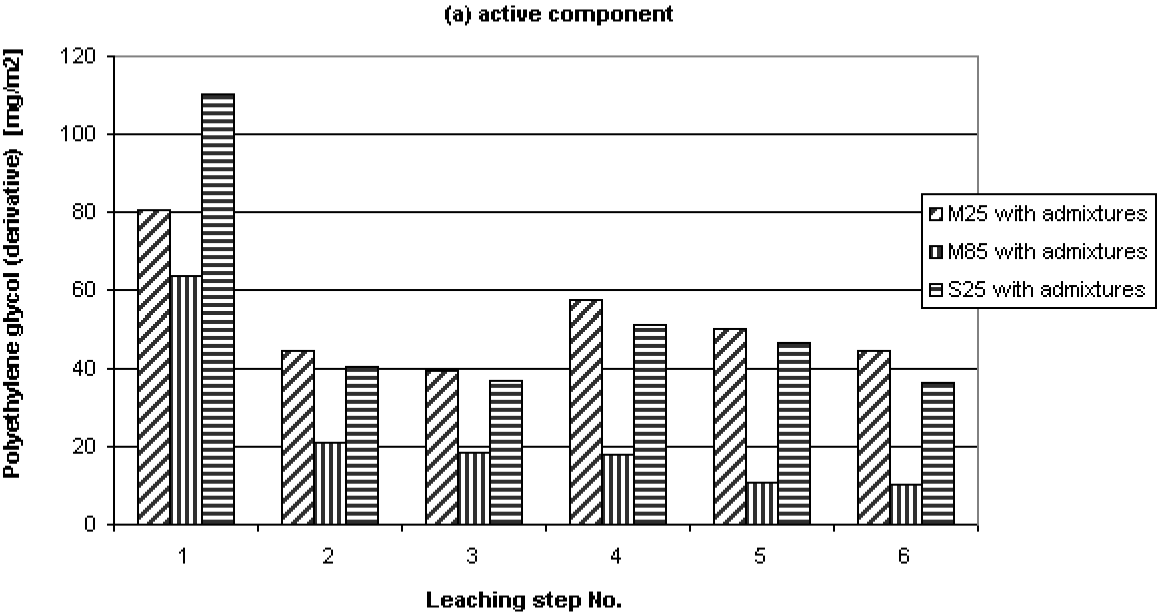
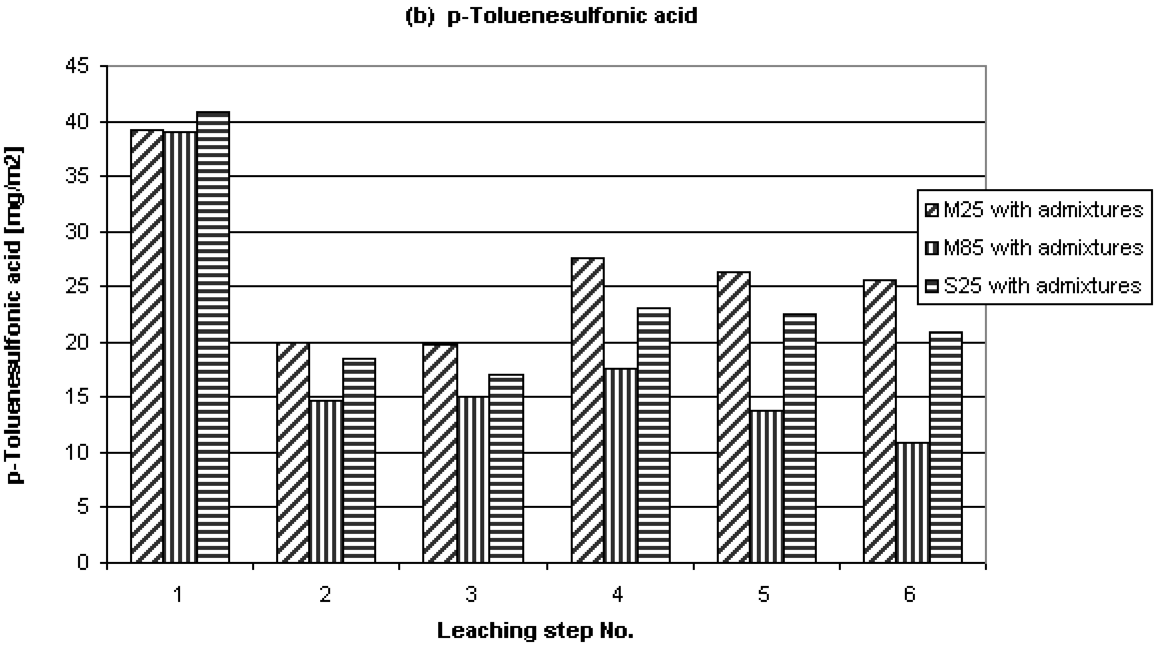


Fig. 4: Amounts of (a) active component, (b) p-toluenesulfonic acid and (c) formiate emitted in leaching steps 1-6



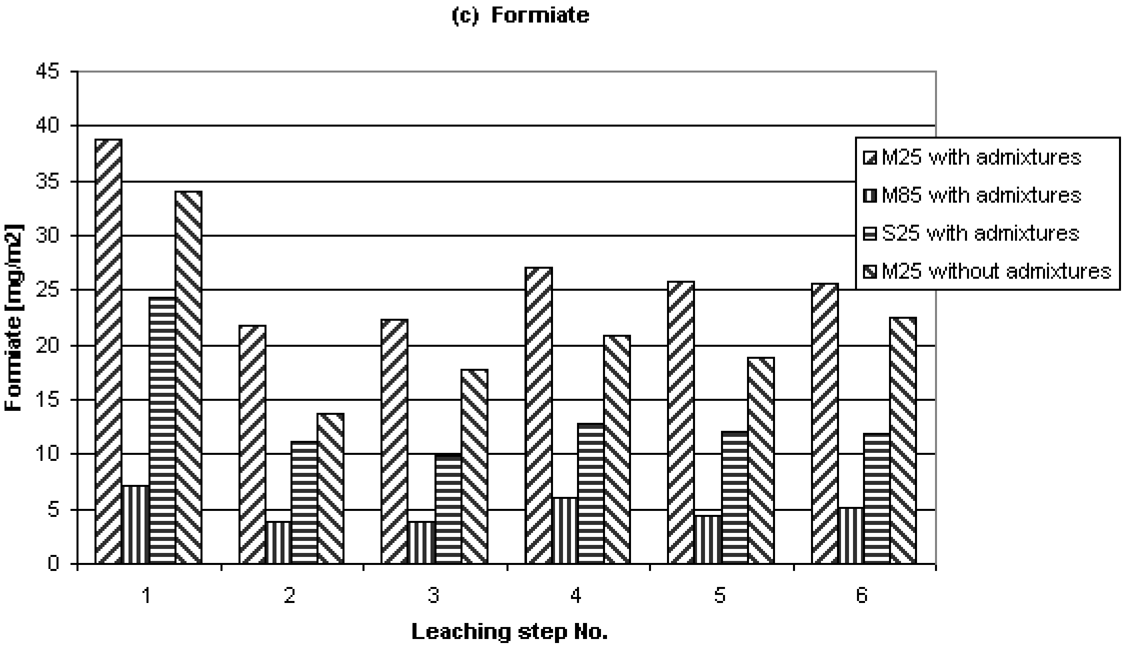


Fig. 4 (continued)

A comparison of leached amounts of the active component for the different samples shows similar proportions for all leaching steps. With the exception of leaching step No. 1 (here S25 > M25) leached amounts decrease in the order:

M25 > S25 >> M85

Leached amounts of the soluble part of the active component correlate with the respective TOC emissions. Again for sample M85 the rapid decrease of the leached amounts of active component in the course of time is remarkable.

Leached amounts of the processing agent p-toluenesulfonic acid and of components independent of admixtures like formiate correlate with leached amounts of the active component. For all leaching steps leached amounts decrease in the order: M25 > S25 >> M85 for p-toluenesulfonic acid and M25 > M25 without admixtures > S25 >> M85 for formiate, respectively.

The similar behaviour of components of the admixture and of components independent of admixtures shows that primarily the pore structure and thus the w/c-ratio is essential for the leaching properties of SCC bodies i.e. the composition of the concrete (content of cement and admixtures) is only secondary.

Moreover a comparison of leached amounts of formiate of sample M25 with that of the reference sample M25 without admixtures shows that the addition of admixtures leads to higher leached amounts even of components independent of admixtures.

Interestingly the rapid decrease of leached amounts of active component observed for sample M85 cannot be observed (in this extend) for the other leached compounds of M85. This rapid decrease (of leached amounts of active component) leads to a depletion of active component relative to the other components in the leachates in the course of time.

Compared to the original product (Polyethylene glycol(derivative)/ p-toluenesulfonic acid = 30) there is a strong depletion of active component for all leachates investigated (Polyethylene glycol/ p-toluenesulfonic acid = 0.8 –2.7). On the one hand this is due to the much stronger adsorption of the active component on cement grains, on the other hand due to its large molecular size the active component presumably shows the smallest diffusion coefficient.

Fig. 5 displays the leached amounts of active component for the SCC bodies investigated in the course of time. Leached amounts of active component summed up over 56 days range from 140 mg/m^2 (M85) up to 320 mg/m^2 (M25).

The respective graphs indicate that for M25 and S25 leaching of the active component is predominantly controlled by diffusion whereas for M85 in the case of the active component the effect of initial wash-off dominates (see discussion).

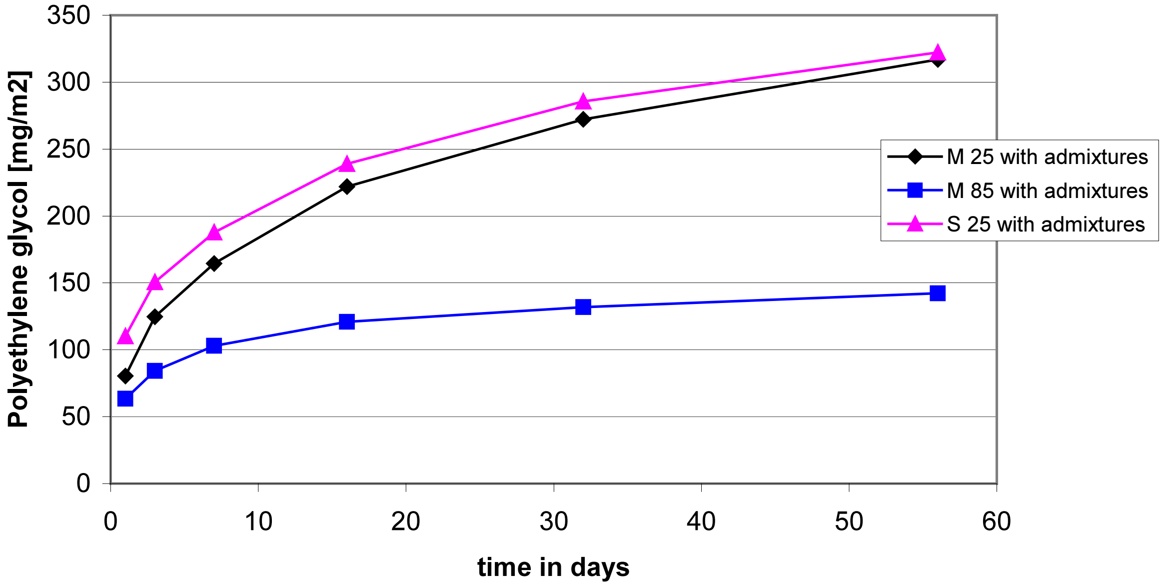


Fig. 5: Leached amounts (summed up) of active component as a function of time.

In Table 5 amounts of active component and p-toluenesulfonic acid originally added and amounts of these compounds leached within 56 days are given.

Table 5: Amounts of active component (soluble part) and p-toluenesulfonic acid (p-TSS) added and amounts of these compounds leached within 56 days.

	Active component added (soluble part) [mg]	p-TSS added [mg]	Active component leached [mg] (after 56 days)	p-Toluenesulfonic acid leached [mg] (after 56 days)	leached/ added amount of active component in % (after 56 days)	leached/ added amount of p-TSS in % (after 56 days)
M25 (w/c = 0.7)	790	24	15	7	1.9	30
M85 (w/c = 0.335)	1900	58	6	5	0.3	9
S25 (w/c = 0.65)	950	29	15	7	1.6	24

For SCC of type M85 (w/c = 0.34) the amount of active component (i.e. soluble part of active component, specifically polyethylene glycol (derivative)) leached over 56 days is about half of that for SCC of type M25 (w/c = 0.7).

Whereas for SCC of type M25 about 2 % (i.e. 15 mg of a total of 790 mg) of the added amount are leached, for SCC of type M85 the fraction of active component mobile in water drops to 0.3 % (i.e. 6 mg of a total of 1900 mg). Although for M85 the added amount of active component is considerably larger (by the factor 2.5) compared to M25, significantly smaller amounts of active component (approx. 50 % of that for M25) are mobile via ground water.

For p-toluenesulfonic acid the recovery rates are as follows: after 56 days 30 % (M25), 24 % (S25) and 9 % (M85), respectively, of the added amounts of p-toluenesulfonic acid are leached. So for M25 the ratio of leached/ added amounts of p-toluenesulfonic acid is by the factor 3.5 higher than that for M85 (compared to a respective factor of 5.5 for the active component). Thus p-toluenesulfonic acid can be considered as significantly more mobile compared to the soluble part of the active component.

4. Discussion

For elutions controlled by diffusion leached amounts of substances (E) are time dependent as follows:

$E = C \sqrt{t_i}$

In a logE/logt-diagram ideally a straight line with slope ½ is obtained.

Yet this kind of presentation has a distinct disadvantage. Due to the summation of leached amounts deviations from diffusion control in a single leaching step have consequences on subsequent leaching steps, too. Thus the interpretation of leaching behaviour in the course of time is made difficult.

Better results are obtained by a differential analysis. Hereby total leached amounts by the end of leaching step i are calculated on the basis of the leached amounts measured for the single leaching step i. For the calculations pure diffusion control is assumed for the entire leaching process [8].

The respective total amounts can be calculated according to

$E_{cal,i} = E_i \sqrt{t_i} / (\sqrt{t_i} - \sqrt{t_{i-1}})$

with:

$E_{cal,i}$: calculated total leached amount after leaching step i

E_i: measured leached amount for leaching step i

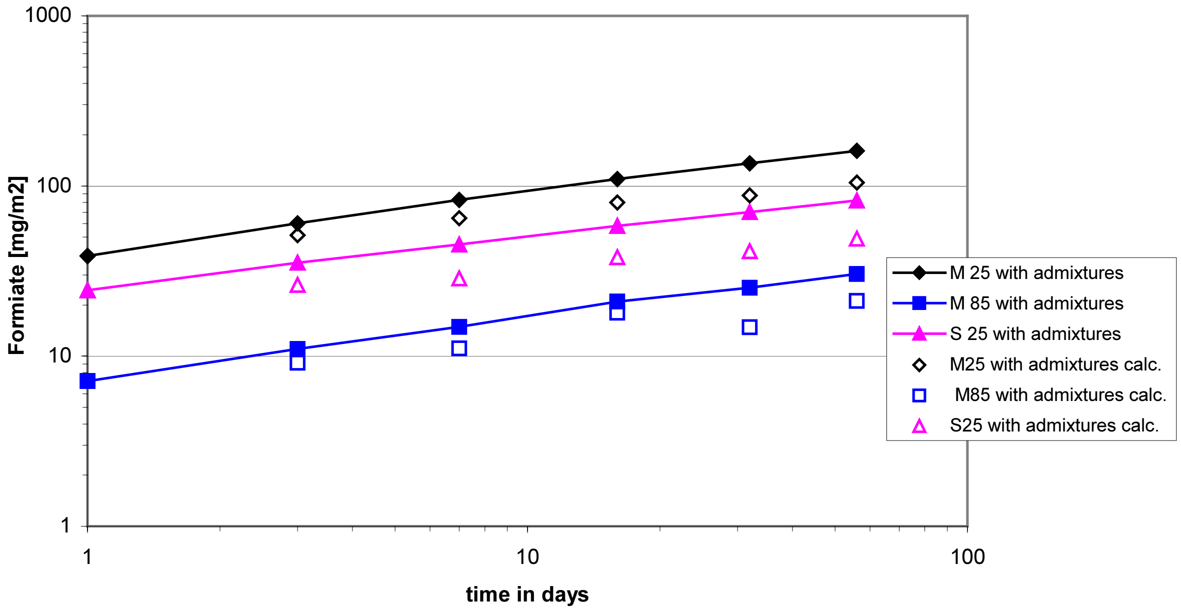
t_i: total time after leaching step i

t_{i-1}: total time before leaching step i

If the measured and the calculated total leached amounts are identical, the elution mechanism is purely controlled by diffusion.

Figures 6 a-c display logE/logt diagrams of measured and calculated leached amounts (summed up) of formiate (a), p-toluenesulfonic acid (b) and the soluble part of the active component (c).

(a) Formiate



(b) p-Toluenesulfonic acid

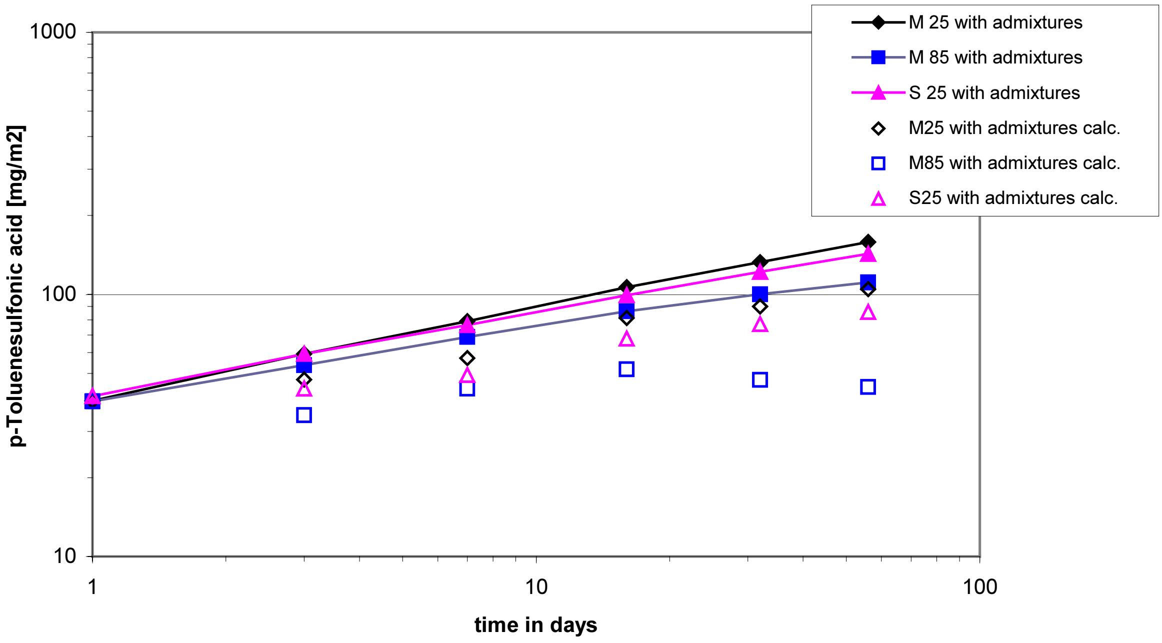


Fig. 6: Experimental and calculated logE/logt-diagrams for formiate (a), p-toluenesulfonic acid (b) and the soluble part of the active component (c) (pure diffusion control is assumed for the calculation).

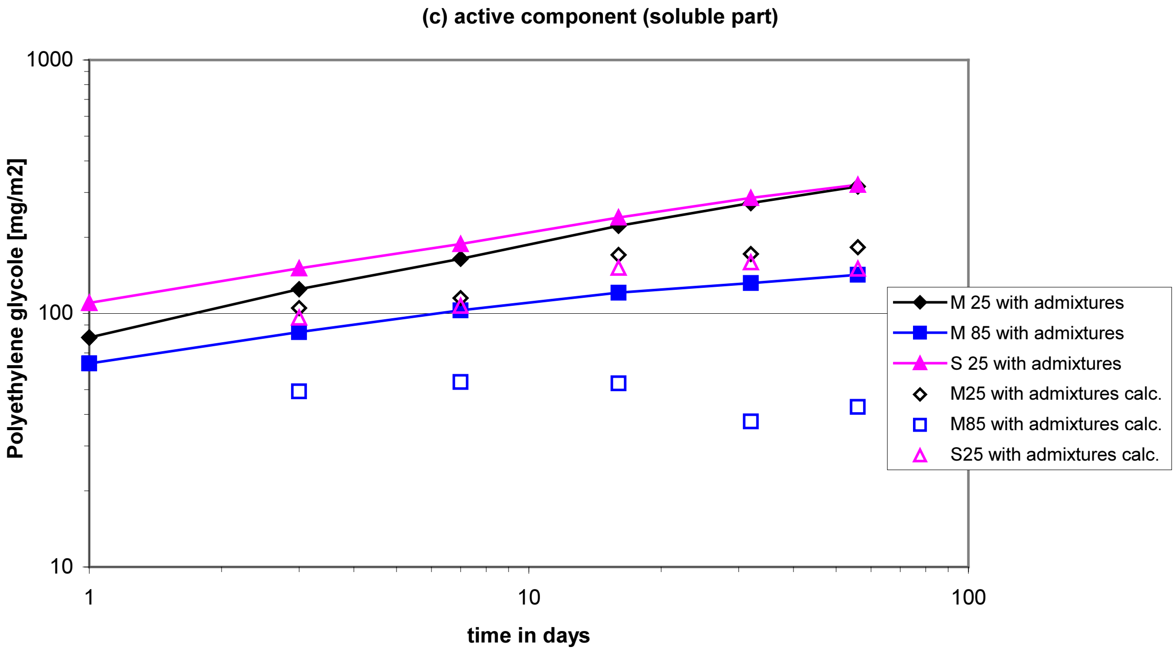


Fig. 6 (continued)

An analysis of the leaching behaviour can be done by classification of the leaching steps in 3 different stages according to a modified version of NEN 7345 [8]:

Initial stage: leaching steps 1 and 2 (0-3 days)

Intermediate stage: leaching steps 2 to 4 (3-16 days)

Final stage: leaching steps 4 to 6 (16-56 days)

In experimental and calculated logE/logt-diagrams, respectively for each stage the slopes of the best fit straight lines were considered. If the slopes of the experimental and the calculated data are equal and thus about ½ leaching is controlled by diffusion for the stage considered. A smaller slope of the calculated data compared to the experimental one may be due to the following reasons: in the initial stage it indicates the effect of initial wash-off, in the final stage it indicates the influence of pore size reduction and/or depletion of the component considered.

For formiate interpretation is quite simple (Fig. 6a): for all three samples calculated leached amounts are slightly smaller than the experimental ones due to initial wash-off of surface bound formiate. This is indicated by the smaller slopes of the calculated graphs compared to the experimental ones in the initial stage. From leaching step No. 2 on graphs of calculated and experimental leached amounts are almost parallel with slopes of about ½.

Except for initial wash-off formiate shows practically no deviation from diffusion control. This is valid for all three SCC types investigated, independent of their different w/c ratios.

A different situation arises for the larger p-toluenesulfonic acid (Fig. 6b): Again the effect of initial wash-off is observed, to a greater extent for the sample with the smallest w/c ratio M85 and to a lesser extent for sample M25. In the intermediate stage for all samples clearly positive slopes of the calculated graphs indicate that leaching is predominantly controlled by diffusion. In the final stage there are large deviations from diffusion control especially for sample M85 (negative slope of the calculated graph in the final stage). In our opinion this is due to the influence of pore size reduction in the course of hydration.

For the large polyethylene glycol(derivate) molecules deviation from diffusion control is even more pronounced (Fig. 6c): In the initial stage the effect of initial wash-off is generally more noticeable in the order M85 > S25 > M25. In the final stage for all samples large deviations from diffusion control are observed (M85 > S25 > M25), which in our opinion is again due to the influence of pore size reduction. Even in the intermediate stage there are pronounced deviations from diffusion control especially for sample M85.

In conclusion for high strength concrete of the type M85 transportation of the soluble part of the active component is almost limited to the effect of initial wash-off. In the course of hydration the concrete matrix gets more and more dense making transportation of large molecules (e.g. active component) increasingly difficult. This effect is possibly due to the hydraulic binding of the added fly ash (see table 1). So it is described in the literature, that the hydration of puzzolanic additives causes a reduction of the pore volume whereby transportation of moisture and material in the concrete matrix is limited [9,10]. For practical use of this concrete this means that after an initial wash-off of surface bound species there is almost no further emission of active component to the ground water making this concrete highly environmentally friendly.

5. CONCLUSION

- For SCC bodies of the powder type (M25, M85) and of viscosity agent type (S25) leaching experiments were performed according to a modified version of the “Standtest Arbeitsprogramm” proposed by the DAfStb.
- Experiments were performed under “worst case” conditions: age of the concrete bodies 3 days and deionized water was used for leaching.
- The organic content of the leachates was determined
    - a) in total by TOC determination
    - b) component-wise by ^{1}H NMR investigation.

In the following some essential results are compiled briefly:

- In the leachates the soluble part of the active component polyethylene glycol (derivative) and the processing agent p-toluenesulfonic acid as main components of the applied superplasticizer can be determined. For the concrete body of the viscosity agent type (S25) components of the viscosity agent (naphthaline sulfonate (derivative), crotonate, 3-hydroxybutyrate) can be determined additionally. It is thus possible to determine the applied superplasticizer as well as the applied viscosity agent by ^{1}H NMR of leachates.
- For all SCC bodies investigated environmental risks are low. Within 24 h the TOC concentration in leachates is about 1-2 mg/l. These concentrations are about 1/10 of the presently discussed tolerable TOC in leachates.
- It was shown that about 60% of the TOC emission is due to concrete admixtures.
- Amounts of leached compounds and TOC emissions decrease in the order M25 > S25 >> M85 ≈ M25 without concrete admixtures. M85 with the lowest w/c ratio (w/c=0.34) and the highest content of admixtures displays the lowest emission rates. So the most important factor for emission is the pore structure and thus the w/c ratio and only to a lesser degree the composition of the concrete (content of cement and admixture).
- Recovering rates for the active component are generally low and vary between 0.3% (M85) and 2% (M25).
- It is shown that transportation is mainly due to diffusion in water filled capillary pores. Deviations from diffusion control are mainly observed in the

initial and final stages of leaching. These deviations are due to the effect of initial wash-off (initial stage) and to the reduction of pore size in the course of hydration (final stage). Effects are most prominent for low w/c ratios (M85) and for large molecules (active component).

- Consequently for high strength concrete M85 transportation of active component is almost limited to the effect of initial wash-off. In the course of hydration the concrete matrix gets more and more dense making transportation of large molecules (active component) increasingly difficult. This effect is possibly due to the hydraulic binding of the added fly ash. For practical use of this concrete this means that after an initial wash-off of surface bound species there is almost no further emission of active component to the ground water making this concrete highly environmentally friendly.

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