INFLUENCE OF LIQUID CONCRETE CURING COMPOUNDS WITH HIGHER CURING EFFICIENCY ON THE RESISTANCE TO SKIDDING OF ROAD SURFACING

EINFLUSS VON FLÜSSIGEN BETONNACHBEHANDLUNGS-MITTELN MIT HÖHERER SPERRWIRKUNG AUF DIE GRIFFIGKEIT VON FAHRBAHNDECKEN

L‘ INFLUENCE DE PRODUITS LIQUIDES DE CUIRE DE BÉTON AVEC UNE EFFICACITÉ SUPERIEURE SUR LA RESISTANCE DE REVÊTEMENTS ROU-TIERS AU DERAPAGE.

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SUMMARY

The testing were done using three new modified curing compounds with different spraying quantities. The test results show a higher curing efficiency and a lower skid resistance when using higher amounts of spraying quantities; that is the same effect as for the well tried compounds. For road surfacing with RC-concrete-aggregates harder requirements are established in the regulations. Under consideration of skid resistance these requirements could be met tightly only in one test. For this reason the skid resistance of concrete surfacing containing RC-aggregates must be re-established by other devices as long as there are not developed new fitting compounds.

ZUSAMMENFASSUNG

Die Versuche wurden mit drei neu entwickelten Nachbehandlungsmitteln mit unterschiedlichen Aufsprühmengen durchgeführt. Die Ergebnisse zeigen, wie bei den bisher verwendeten Mitteln, bei Ansteigen der Aufsprühmenge ein Ansteigen der Sperrwirkung und ein Abfallen der Griffigkeit. Die erhöhten Anforderungen an die Sperrwirkung bei Verwendung von Fahrbahndecken mit RC-Betonzuschlag konnten unter Berücksichtigung der Griffigkeit nur in einem Fall knapp erfüllt werden. Daraus folgt, dass bis zur Entwicklung geeigneter Nachbehandlungsmittel, die Griffigkeit von Fahrbahndecken mit RC-Betonzuschlag nachträglich wiederhergestellt werden muss.

RESUME

Pour les expériences trois nouveaux produits de cuire de béton étaient appliqués en différentes quantités. Les résultats montrent - comme d'habitude - que l'efficacité augmente avec la quantité appliquée et la résistance au dérapage diminue en même temps. Les exigences élevées à l'efficacité pour les revêtements routiers avec RC-agrégat pouvaient être remplis tout juste seulement dans un cas, en respectant en même temps la résistance au dérapage. En conséquence, la résistance au dérapage de revêtements routiers avec RC-agrégat doit être reconstituée après coup, avant d'avoir trouvé des produits de cuire de béton conforme aux exigences élevées.

KEYWORDS: Concrete, curing, curing compounds, curing efficiency, skid resistance

1. INTRODUCTION

Today, structural concrete elements are cured in summer, as far as it is necessary because of extreme weather conditions, with steam-tight, transparent plastic foils or, mainly on horizontal surfaces as e. g. concrete ceilings or concrete roads, with liquid, sprayable curing compound films. Such a curing prevents widely a strong drying of the young concrete near the surface. Natural and bending stress which arise by drying shrinkage in a young age, are reduced by that. The danger of crack formation because of drying is thereby antagonised.

For this reason, concrete industry has already been offering for many years liquid concrete curing compounds. The most important characteristics these curing compounds show, are in a positive sense the curing efficiency and as a negative effect the influence on the skid resistance of concrete roads. These two characteristics operate contrarily with increasing spraying quantity. For good reasons, minimum values for the curing efficiency as well as a limit for skid resistance which must not be undershot are determined in the Technischen Lieferbedingungen [1].

A steadily further developing circular flow economy which aims to protect the natural raw materials as well as to save ground storage space, gains increasingly in importance. Thus, using recycling aggregates (RC-aggregates) also is a current practice since long ago. Because of the higher demand in water of RC-aggregates due to its porosity and the thus possible interior drying of the RC-concrete the thoroughly curing of the surface still gains more importance than for concrete made from unused aggregates.

In the draft of “Merkblatt zur Wiederverwendung von Beton aus Fahrbahndecken” [2] it is therefore fixed under point 7.5 that for road surfacing with RC-concrete aggregates curing compounds which should reach a curing efficiency index S of 85% at least have to be used.

The producer of concrete curing compounds fear that a negative effect on the skid resistance caused by this requirement may occur. The research project initiated because of these objections is sponsored by funds of the Bundesministerium für Verkehr, Bau und Wohnungswesen.

The first part of the research project is the basis for this publication.

2. TESTING PROGRAMME

For the examinations, 3 curing compounds were chosen, two of them with increased reflectance value; none of the three compounds is surveyed according to the Technischen Lieferbedingungen [1]. Specifications of the curing compounds are included in table 1.

Table 1: Specifications on the curing compounds

Curing compounds	Active substance	Solvent	Higher reflectance factor	Colour
A	paraffin	water	no	white
B	paraffin + pigment	water	yes	white
C	paraffin + pigment	water	yes	white

The curing efficiency was tested according to the normal spraying quantity [1] given by the producer, as well as additionally with the 1,25- and 1,5- times higher spraying quantity. Also the skid resistance was tested with these spraying quantities. All tests were executed twice each.

3. TESTS AND TEST RESULTS ON THE CURING COMPOUND FILMS

The fine-grained concrete and the specimens were produced according to the Technischen Lieferbedingungen [1]. The volume weight for all mixtures was 2.30 to 2.31 kg/dm^3, the air content between 2.5 and 3.0 % by volume and the temperature of fresh concrete between 19 and 22 °C.

In each concrete placement process 3 specimens for the 1.0- ,1.25- and 1.5-fold spraying quantity were produced at the same time together with 3 reference specimens from the same mixture.

The specimens were stored in a climatic chamber at 30 ± 2 °C and 40 ± 3 % relative air humidity. The hardly perceptible air movement in the climatic chamber could not be registered by the institute's anemometer.

When becoming mat dry, about 60 to 80 minutes after addition of water, the broom finishing was spread as uniformly as possible in direction of the edging side of specimen with a natural hair brush by hand.

After another 30 to 50 minutes, after repeated becoming mat dry, the specimens were sprayed with the curing compound. The spraying mass was controlled by scale. The divergence of the scheduled value of ± 0.1g was tolerated, this corresponds to about 1 to 2 % of the spraying mass.

3.1 Curing efficiency index

The curing efficiency index was detected according to the Technischen Lieferbedingungen [1] on specimens which were spread with the 3 curing compounds A, B and C with the 1.0- , 1.25- and 1.5-fold spray mass.

In doing so, it is to be annotated that the recommended spray mass showed an optically well covering view with all 3 compounds, whereas already for a mass increased by 25 %, slightly swimming effects occurred for compound A (draining). The quantity increased by 50 % showed only for compound C no jut out liquid.

The concrete specimens as well as the specimens to determine the loss of solvent were stored until the end of curing efficiency testing, which means 7 days, in the climatic chamber with 30°C and 40% relative air humidity. For each compound, 3 specimen for each spray mass as well as the reference specimen were stored on the mobile rack in such a way that the specimens with the 1.0-fold quantity were on top, followed downwards by the subsequently higher spray mass, whereas the reference specimens were spread on the lowest rack floor.

The curing efficiency index S follows from the arithmetic mean of the proportions of water emission of the coated specimens on the first, third and seventh day after production to the at the same time detected water emissions of the untreated specimens, considering the loss of solvent of curing compound. The curing efficiency indexes detected in this way are listed for the 3 curing compounds, separated according to their apply masses as particular and mean values in table 2 and demonstrated in figure 1.

Table 2: Curing efficiency index with different spraying quantities

Curing Compound	Dosage	Curing efficiency index				Skid resistance		
		Particular values			Mean value	Particular values		Mean value
Unit	g/m^2	%			%	Scale parts		Scale parts
A	140 ≙ 1,0-fold	76		77	77	60	56	58
	175 ≙ 1,25-fold	84		89	87	56	54	55
	210 ≙ 1,5-fold	89		92	91	54	46	50
B	140 ≙ 1,0-fold	74	62	64	67	63	65	64
	175 ≙ 1,25-fold	81	74	71	75	65	61	63
	210 ≙ 1,5-fold	87	81	80	83	64	60	62
C	150 ≙ 1,0-fold	79		79	79	59	57	58
	187,5 ≙ 1,25-fold	86		88	87	55	53	54
	225 ≙ 1,5-fold	91		91	91	47	47	47

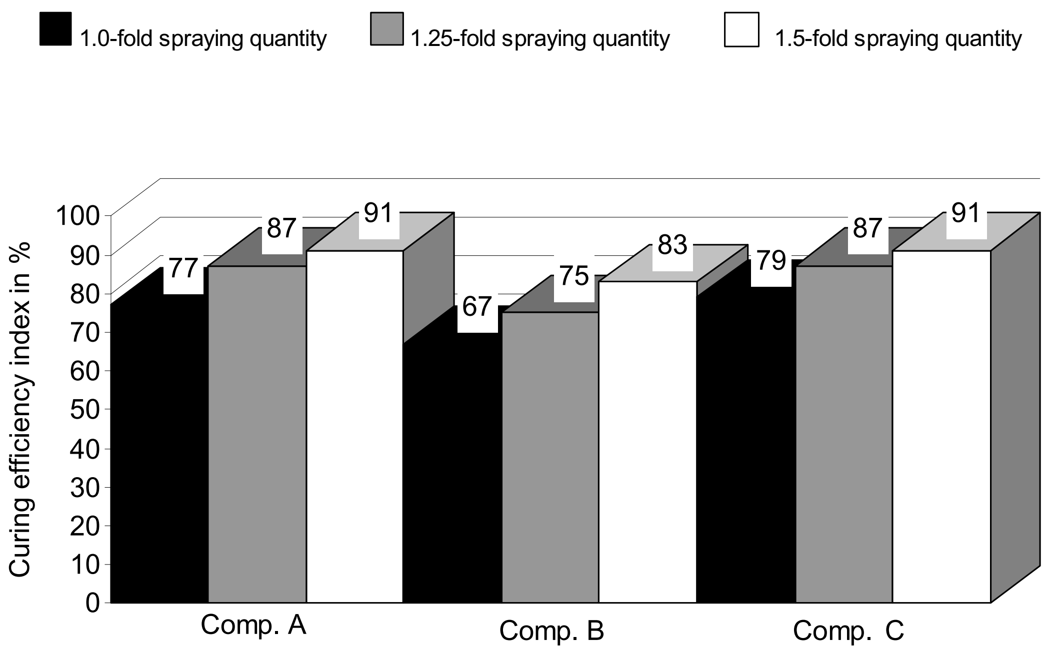

Figure 1: Curing efficiency index of curing compounds A, B and C with 1.0-, 1.25- and 1.5- fold quantity

Due to the relatively great difference between the first and second testing for compound B, a third test was performed, which verified mainly the results of the second test. However, the occurrence of differences of this kind may not satisfy.

3.2 Skid resistance

The specimens produced for the skid resistance were sprayed and tested as well with the 1.0-, 1.25- and 1.5-fold spraying quantity contrarily to the specifications given in the Technischen Lieferbedingungen [1].

Also here it is to be mentioned that a supernatant was established on the concrete's surface using a 1.5-fold spraying quantity for compound A and B.

The coated specimens were stored in a climatic chamber at 20 °C and 65 % relative air humidity until testing at the age of 28 days, while the reference specimen stayed in climate 20/100 for the first 7 days.

The skid resistance is determined with the skid resistance tester as frictional resistance according to the Arbeitsanweisung für Griffigkeitsmessungen [3] and indicated in scale parts. For the measurement the specimen is dosed with water in such a way that a closed water film develops on its surface.

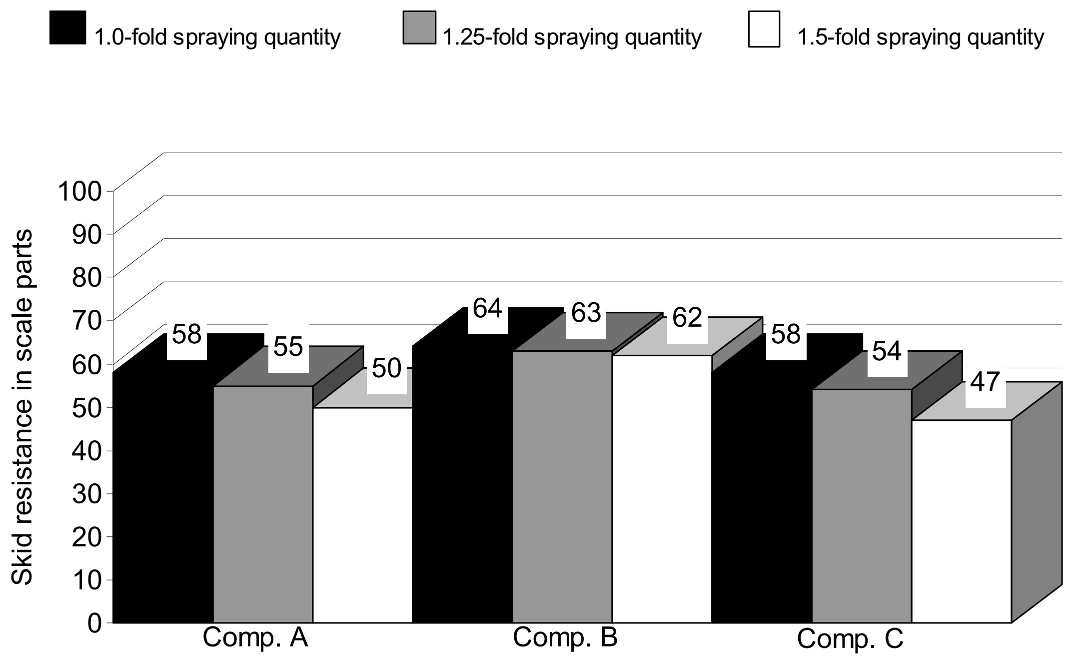

Figure 2: Skid resistance of curing compounds A, B and C with 1.0-, 1.25- and 1.5-fold quantity

For the compounds B and C, it is to be mentioned that already in the first swing parts of the curing compound, which than adhered to the sliding device, were lifted off caused by the pressure of the sliding device. For this reason, the measured values increased while testing, until a static status was finally reached after up to 11 swings of the skid resistance tester.

The particular measured values of both testing and the generated mean values are listed in table 2, The mean values are also shown graphically in figure 2.

4. DISCUSSION

The average curing efficiency indexes obtained while testing came up to 67, 77 and 79 % for the recommended spraying quantity. With this, compound B do not fulfil the requirement of 75 % stated in the Technischen Lieferbedingungen [1].

As expected, an increase of the curing efficiency index abandoned, despite of the partly unsatisfactory adherence of the compound, which was already pointed out above.

The limit value of 85% stated in the instructions [2] is not reached or exceeded, respectively, until the 1.25-fold spraying quantity of compounds A and C. Compound B stayed also with 1.5-fold spraying quantity under this limit value with 83%.

The obvious improvement of the curing efficiency of compound A and C of about 10% with a 25% higher application and a much smaller (about 4%) improvement for a further increase of spraying quantity until the highest quantity allowed (150 % altogether) is remarkable. This might indicate that the curing efficiency index of each curing compound converges an ultimate value when the spraying quantity is increased, whereas this ultimate value needs not to correspond to the complete preventative of evaporation. The results of a former research project [4], [5] are comparable, where no further improvement of the curing efficiency from a increase of 50% to 75 % of the spraying quantity could be stated.

The skid resistance reduces for all compounds with increasing spraying quantity. For 3 of 9 single tests with 1.5-fold spraying quantity (compound A and C), it falls below the ultimate value of 50 of the Technischen Lieferbedingungen [1] with 46 and 47 scale parts. According to the criteria of the Technischen Lieferbedingungen, compounds A and C should be assigned to those curing compounds that may be released to traffic after one month at the earliest, whilst the special quality of short term release to traffic could be evidenced for compound B, too. In consideration of the insufficient curing efficiency, the reached high skid resistance seems to be feasible.

The influence of the curing efficiency on the skid resistance is shown in figures 3 and 4. To evaluate the results, the ultimate value of curing efficiency (≥ 85%) proposed in the instructions [2] and the ultimate values of the Technischen Lieferbedingungen [1] for the curing efficiency (≥ 75 %) and the skid resistance (≥ 50 scale parts) are marked in these figures. The sector in which the requirements according to the instructions [2] are fulfilled, is marked in light grey, the further difference sector to [1] is marked darker.

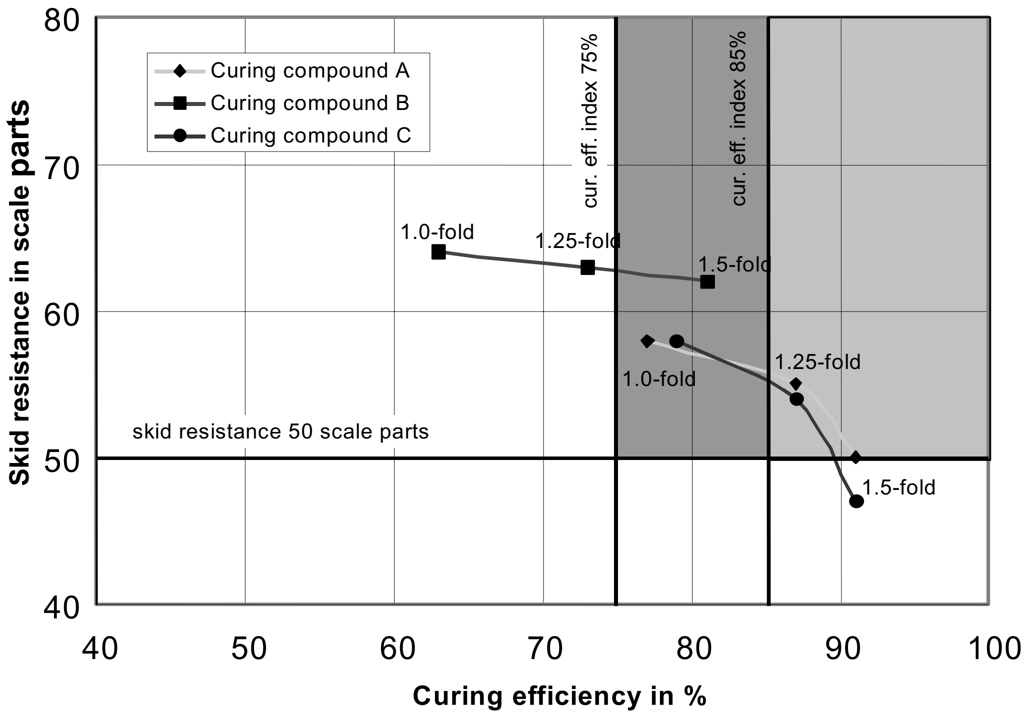

Figure 3: Influence of the curing efficiency index of curing compound A, B and C on the skid resistanca

Figure 3 shows that all curing compounds have an improved curing efficiency and at the same time a reduction of the skid resistance using a higher spraying quantity. According to the quoted harder criteria of the instructions [2], a sufficient curing efficiency together with at the same time satisfactory skid resistance is to be evidenced for 3 of 9 tests, whereas the requirements according to [1] are fulfilled by seven compounds.

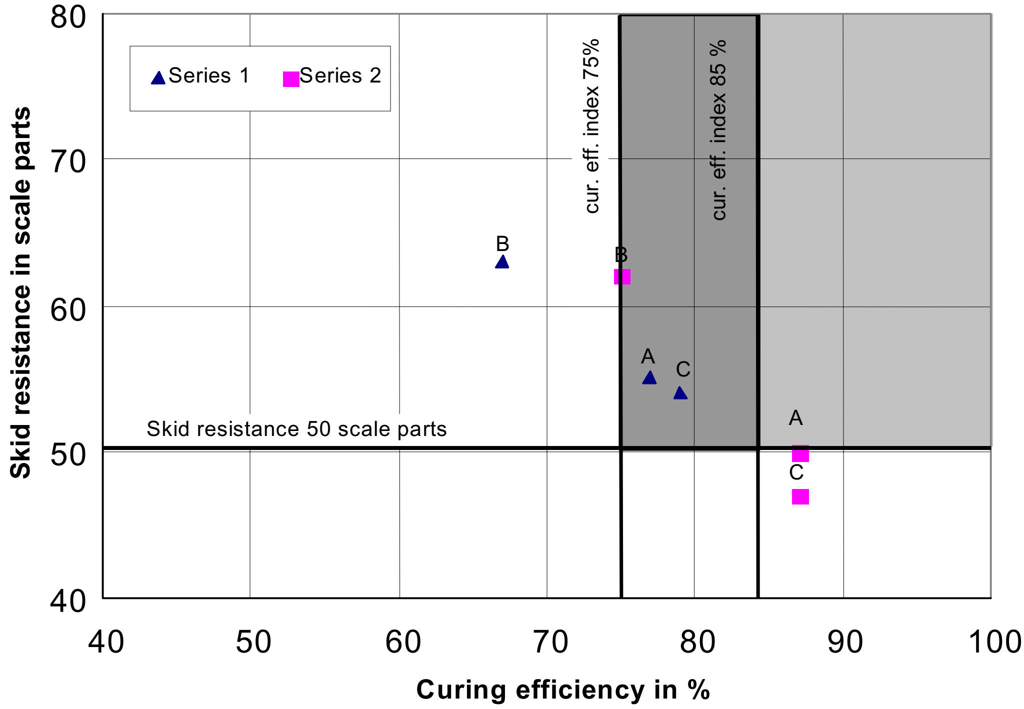

Figure 4: Influence of the curing efficiency of the curing compounds A, B and C on the skid resistance (series 1: 1.0-fold spraying quantity for efficiency and 1.25-fold spraying quantity for skid resistance; series 2: 1.25-fold spraying quantity for efficiency and 1.5-fold spraying quantity for skid resistance)

In figure 4 the results of curing efficiency are allocated to those of the skid resistance in the way they are required by the Technischen Lieferbedingungen [1]. That means, the requirements to curing efficiency must be fulfilled with the 1.25-fold spraying quantity of the skid resistance. Due to the already mentioned defaults, the quantity for the skid resistance (1.5-fold) to be appropriated to the spraying quantity for the curing efficiency increased by 25 % diverges slightly from the actual quantity.

The tightened requirements are only shortly fulfilled by compound A with the 1.25-fold spraying quantity, whereas 4 of altogether 6 tests are within the previous limits of requirements [1].

6. SUMMARY

The results correspond throughout to the previous perceptions, that higher spraying quantities of curing compounds implicate an increase of curing efficiency and a reduction of skid resistance.

The examinations carried out so far show obviously, that an increased curing efficiency of a curing compound may not be required that easily as it would be desirable when using RC-aggregates in concrete roads. As presumed, an increased curing efficiency influences the skid resistance of the concrete surface that negative that the requirements on curing efficiency as well as on the skid resistance are met only in one case tightly.

If the requirements on an increased curing efficiency on road surfaces with RC-aggregates should be maintained, it seems thus to be reasonable to either re-establish the skid resistance with other devices, as e.g. sandblasting, or to develop curing compounds on a modified active substance basis and to include them in the examinations.

LITERATURE

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