FRESH PROPERTIES OF SELF-COMPACTING CONCRETE (SCC)

FRISCHBETONEIGENSCHAFTEN VON SELBSTVERDICHTENDEM BETON (SVB)

PROPRIETES DU BETON AUTOPLAÇANT (BAP) FRAIS

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SUMMARY

Several methods existing for testing the flowability of self-compacting concrete (SCC). In this article a simple method – based on the so-called J-Ring test – is presented which allows the quantification of the part of the blocked concrete volume. Furthermore some empirical relationships between different test results are presented which were found for the tested SCC mixtures.

ZUSAMMENFASSUNG

Es gibt eine Reihe von verschiedenen Prüfmethoden zur Bewertung der Fließfähigkeit von Selbstverdichtendem Beton (SVB). In diesem Artikel wird eine einfache Methode zur Quantifizierung des blockierten Betonvolumens vorgestellt, die auf dem sogenannten J-Ring Versuch beruht. Des Weiteren werden empirische Zusammenhänge zwischen den einzelnen Messwerten angegeben, die für die untersuchten SVB-Mischungen gefunden wurden.

RESUME

Il existe une série de différentes méthodes de contrôle pour évaluer la fluidité du béton autoplaçant (BAP). Dans l'article présent, une méthode simple pour quantifier le volume de béton bloqué est présentée Cette méthode est basée sur le test « J-Ring ». Des relations empiriques entre les valeurs mesurées obtenus pour les différents BAP examinés sont également présentées.

KEYWORDS: Self-compacting concrete, SCC, blocking, J-Ring, blocking ratio, step of blocking

1. INTRODUCTION

Self-compacting concrete (SCC) was developed in the middle of the 1980's in Japan. SCC flows alone under its dead weight up to levelling, airs out and consolidates itself thereby without any entry of additional compaction energy and without a nameable segregation. SCC owns over three key characteristics which are shown in fig. 1. These characteristics were made possible by the development of highly effective water reducing agents (superpalsticizers), those usually based on polycarboxylate ethers. The mixture composition of SCC deviates from conventional concrete. The powder contents of SCC are normally lying (in some cases even considerably) above those of conventional concrete.

1. **Filling Ability:**	Ability of to fill a formwork completely under its own weight.
2. **Passing Ability:**	Ability to overcome obstacles under its own weight without hindrance. Obstacles are e.g. reinforcement and small openings etc.
3. **Segregation resistance:**	Homogeneous composition of concrete during and after the process of transport and placing.

Fig. 1: The three key properties of fresh self-compacting concrete

Because of its special fluidity, SCC requires modified fresh concrete testing methods compared with conventional concrete. These testing methods are specified e.g. in [1] and [2]. The difficulty consists of the fact, that SCC responds very sensible to deviations of mixture proportions. Already slightest deviations can lead to a concrete that does not obtain one ore more of these key characteristics. This is usually connected with substantial lack of the finished construction unit, which lower not least the durability drastically and make in the worst case a construction useless. In the following the filling and the passing ability will be considered in a greater detail.

2. QUANTIFICATION OF THE PASSING ABILITY

It was already mentioned that SCC has to have the ability to flow through narrow openings without hindrance. This means that the so-called blocking of coarse aggregates through bridging has to be avoided. Fig. 2 shows the mechanism of blocking of coarse aggregate by a two-dimensionally illustrative model.

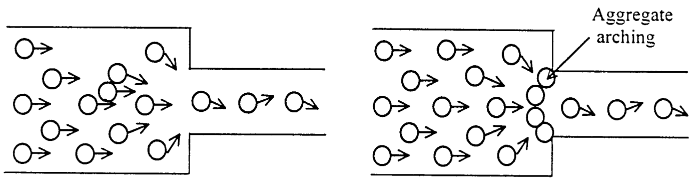

Fig. 2: Mechanism of blocking [3]

One possibility for assessment of the blocking behaviour is to perform the well-known slump flow test under use of the so-called J-Ring (

Fig. 3).

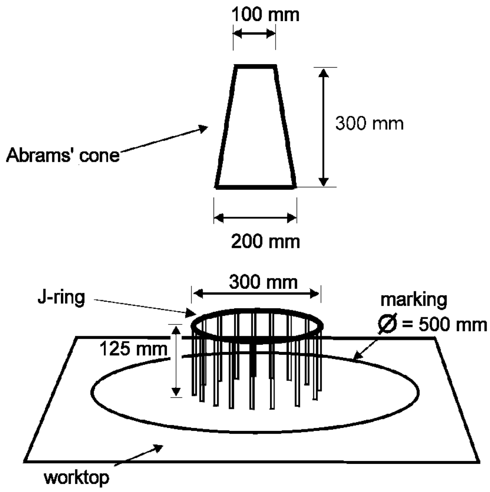

Fig. 3: Necessary equipment for performing the J-Ring test [5]
(schematic, just before setting the Abram's cone on the worktop)

After the lifting motion of the Abrams' cone the concrete must flow under its dead weight through the steel rods which shall simulate the flow through reinforcement in a real formwork. Fig. 4 shows a photography of the concrete shape which arose after the J-Ring test was performed. Dependent on the mixture composition (and also on the number of steel rods) a clearly increased content of coarse aggregates can be observed within the ring despite reaching a defined spread diameter. Apparently blocking can be determined. A second parameter (beside the spread diameter s_J and the flow time $t_{500,J}$) can be quoted by measuring the height difference of the concrete behind and in front of the rods of the J-Ring. A mean value can then be calculated of four measuring points (two directions each with two measuring points). This mean value is defined as the step of blocking st_J. The method of measuring the step st_J was also stated in [6].

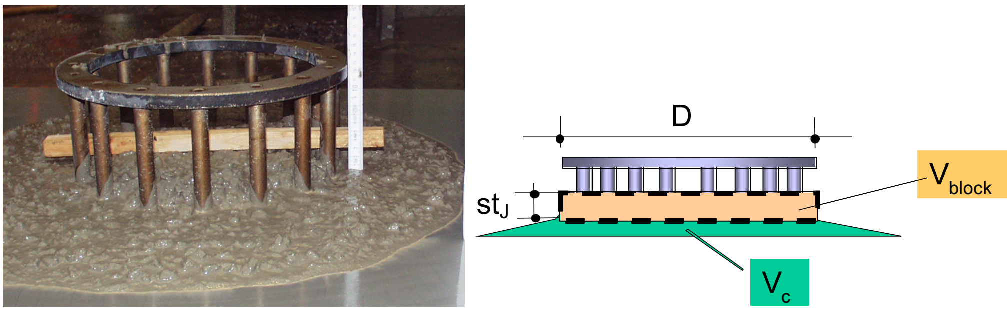

Fig. 4: Photography of the measurement of the step (J-Ring with 16 rods, $st_J \approx 30$ mm) and idealised spread of concrete for calculation of the blocking index [4].

From the measured step st_J the portion of the blocked concrete volume can be derived (Fig. 4). Thus a blocking index β as the ratio of the blocked concrete volume V_{block} related to the total concrete volume V_C can be calculated (eq. 1). The part of the blocked concrete volume β is then directly proportional to the step st_J. It has to be annotated that the concrete shape isn't exactly plane. It is rather curved due to the concrete yield value and the stresses caused from dead weight. This is the reason why a step st_J can be measured despite apparently blocking is not determined. But for a first simplification the concrete shape can considered to be plane.

$$\beta = \frac{V_{block}}{V_c} = \frac{\frac{\pi D^2}{4} \cdot st}{V_c} = \frac{\frac{\pi D^2}{4}}{V_c} \cdot st_J \qquad \text{(eq. 1)}$$

with:

β	blocking index
V_C	whole concrete volume (volume of the Abram's cone)
V_{block}	blocked concrete volume
st_J	step of blocking, mean value measured in two directions each with two measuring points at the ends
D	diameter of the idealised concrete shape

3. TEST RESULTS

A set of fresh concrete investigations were accomplished in the context of an European GROWTH project called „Testing SCC" (GRD2-2000-30024) which served to investigate methods for quantification of the blocking behaviour of SCC. Therefore the filling and passing ability of fresh concrete SCC mixtures (contained crushed granite as coarse aggregates) have been assessed. The spread diameters and the flow times of the slump flow test (s, t_{500}) respective the J-Ring test (s_J, $t_{500,J}$), the step of blocking st_J and the flow time t_V of the so-called V-funnel test were measured.

SCC mixtures are often characterized by their funnel time t_V (which is often used as a degree of the apparent viscosity of mix) and their spread diameter s which stands for the filling ability. Fig. 5 gives an overview over the characteristic fresh concrete parameters of the tested mixtures; the results are ordered by the step st_J . Apparently no blocking could be observed if the step st_J was below 10 mm.

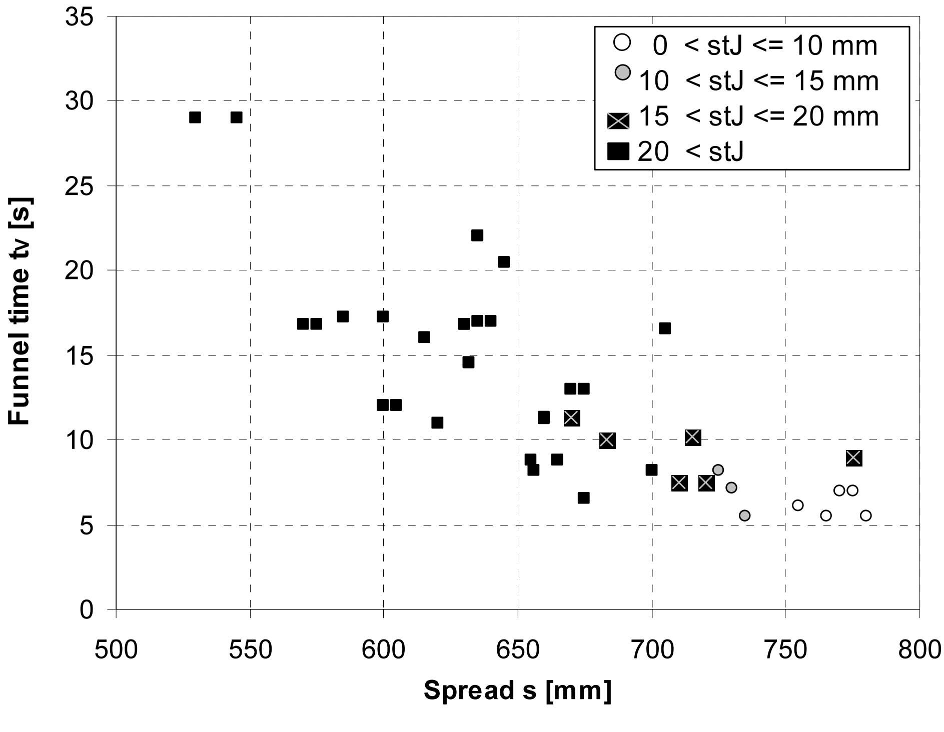

Fig. 5: Properties of tested SCC mixtures

It can be annotated to Fig. 5 that the blocking behaviour varies from non blocking to strong blocking within the range of $650 < s < 770$ mm.

Fig. 6 shows the interrelation between the spread s_J and s. The difference $\Delta s = s - s_J$ between the two diameters decreases with an increasing filling ability. However the there exists a large scatter (Fig. 7).

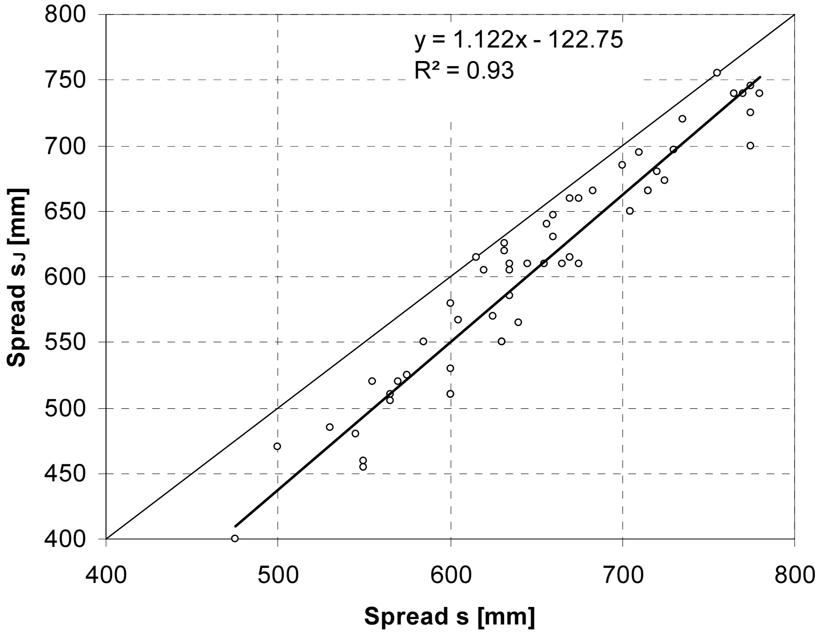

Fig. 6: Spread s_J (J-Ring) vs. spread s (slump flow)

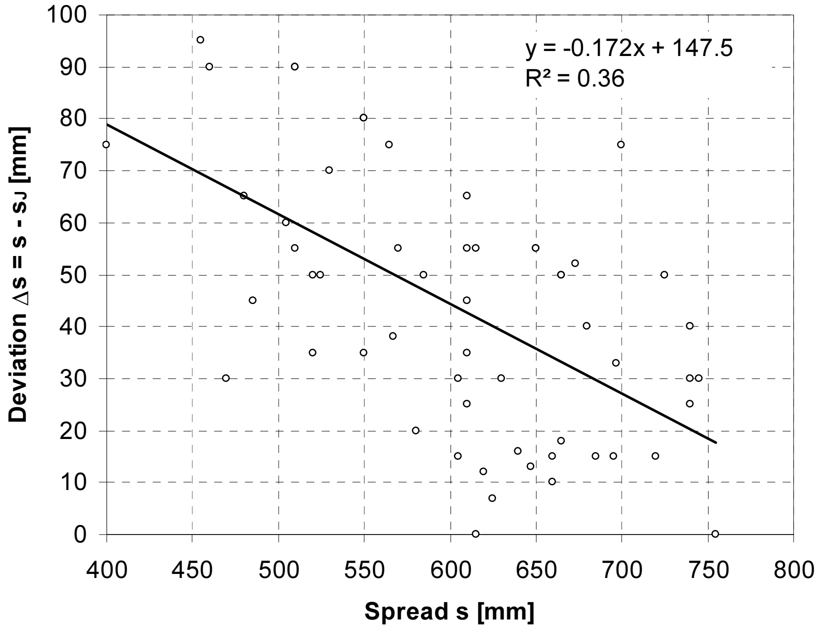

Fig. 7: Difference Δs vs. spread s

It was shown in the previous chapter that the part of the blocked concrete volume V_{block} is proportional to the step st_J. It might be therefore of interest if there exists a relationship between the difference Δs and the step st_J (Fig. 8).

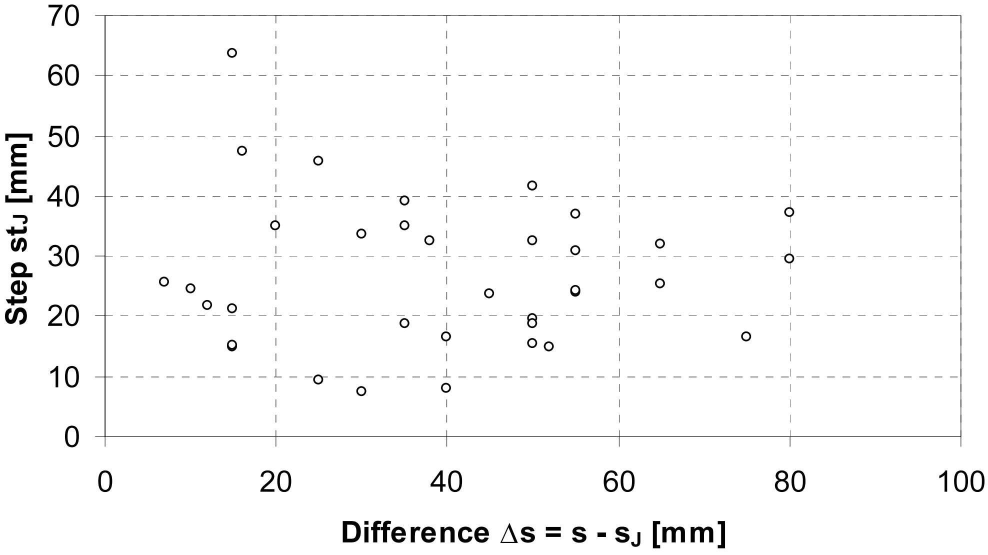

Fig. 8: Step st_J vs. difference of spread Δs

Even the difference Δs is limited to 30 mm, the step st_J scatters between 8 mm (no blocking) and 65 mm (strong blocking). It can be derived from Fig. 7 and Fig. 8 that a Δs-criterion (alone) is not suitable for quantification and evaluation of the blocking behaviour of a SCC mixture.

In the J-Ring test and also in the V-funnel test the concrete has to overcome a narrow opening obstacle. It can therefore assumed that there also exists a relationship between the measured parameters of these two tests. Fig. 9 contains the step st_J and the flow time t_V.

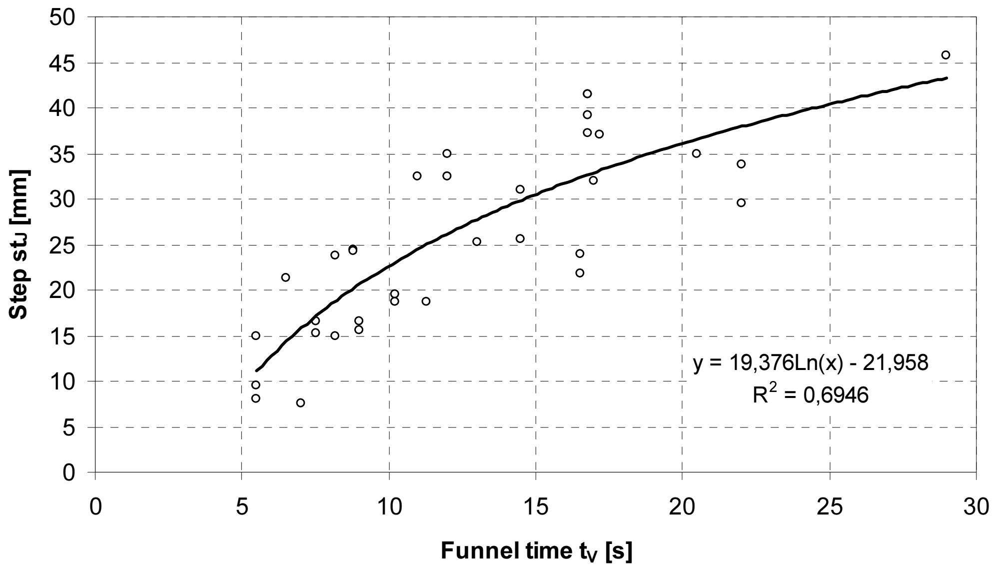

Fig. 9: Relationship between the blocking behaviour and funnel time

The funnel time t_V is often used to estimate the apparent viscosity of a mixture. However, many factors are playing a role and influencing the result of the V-funnel test: the amount, shape and size distribution of aggregates and also the viscosity and amount of paste etc. This means that the funnel time does not necessarily correspond with the viscosity of a mix measured e.g. by a rheometer.

There was also found an empirical relationship between the spread s_J and the step st_J (Fig. 10). The relatively good stability index of $R^2 = 0,95$ can attributed to the fact that a geometric relationship exists among these parameters (the volume of the Abrams' cone is fixed of about 5,5 litres).

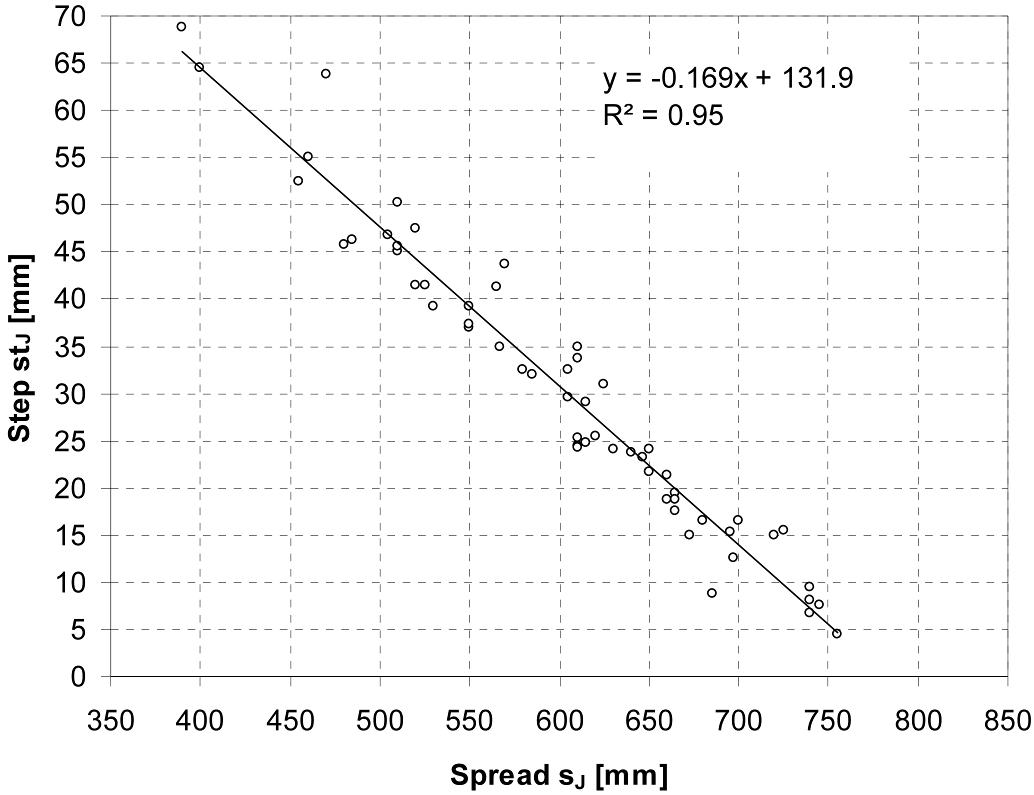

Fig. 10: Step st_J vs. spread s_J

It was already shown that the blocked concrete volume is linked with the funnel flow time t_V. But also the segregation resistance is linked with the apparent viscosity of a SCC mixture. To achieve a sufficient resistance to segregation, the funnel time may not fall below a minimum value. From practical sight of view it would be convenient to know a reliable relationship between the flow times t_{500} respective $t_{500,J}$ and the funnel time t_V of a SCC mixture. Then the V-funnel test could be skipped. The relationships which were found between the flow times are plotted in Fig. 11 and Fig. 12. The correlation between the t_{500}-value and the t_V-value is for the slump flow test better than for the J-Ring test.

However, the measurement of the t_{500}-value is more operator influenced than the measurement of the V-funnel flow time t_V.

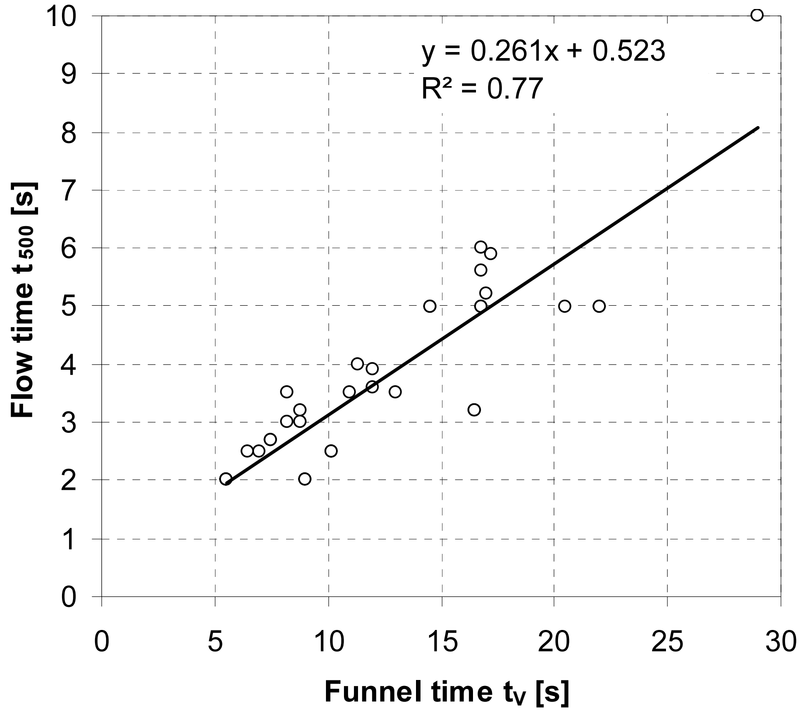

Fig. 11: Relationship between the t_{500}-value (slump flow test) and the funnel time

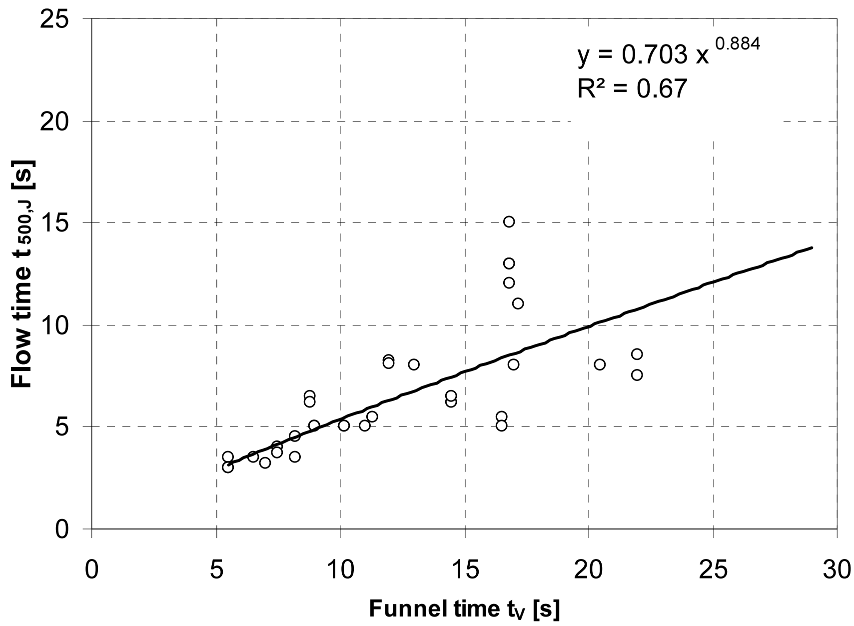

Fig. 12: Relationship between the $t_{500,J}$-value (J-Ring test) and the funnel time

4. SUMMARY

Several methods existing for testing the filling and passing ability of SCC. In this article a simple method was presented which allows the quantification of the part of the blocked concrete volume with the so-called J-Ring test. It could be shown that the blocked concrete volume is proportional to the step of blocking which adjusts itself directly in front and behind the steel rods of J-Ring. This method was compared with the conventional method which evaluates the blocking behaviour of SCC by the difference of spread between the slump flow test and the J-Ring test. It could be derived that the conventional method is not suitable to quantify the blocking behaviour. Also some empirical relationships between different test results were presented which had been found for the tested SCC mixtures.

5. REFERENCES

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