



# Self Compacting Concrete

## Actual status (and future development) in Europe

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# Self Compacting Concrete (SCC)

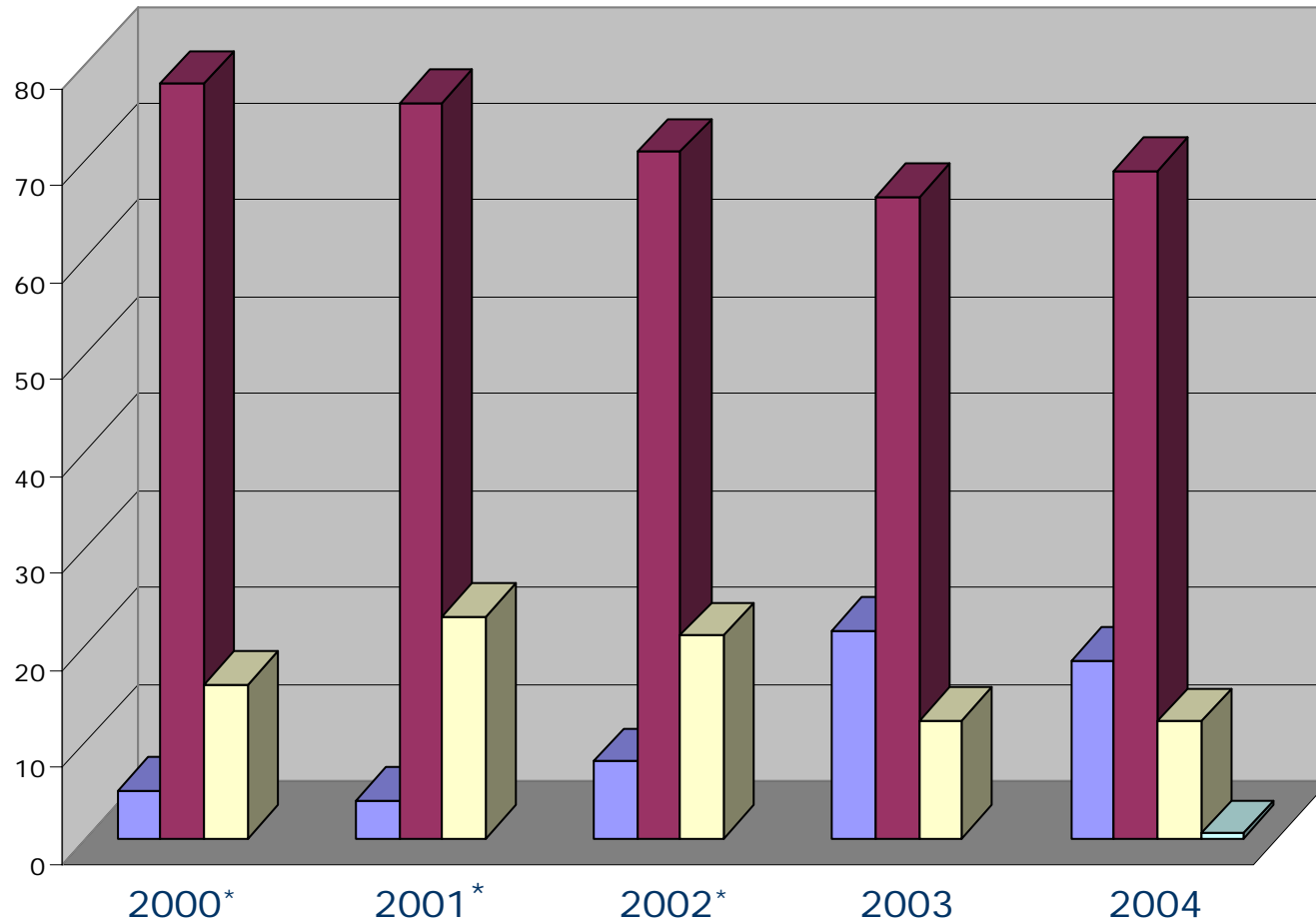
- ▶ is an advanced structural material
- ▶ gives improved finish and appearance
- ▶ allows for improved placing methods
- ▶ provides significant safety benefits
- ▶ offers new design opportunities
- ▶ reduces manual handling

So, why is SCC not widely used ... ?





# Consistence in Readymix Concrete [%]

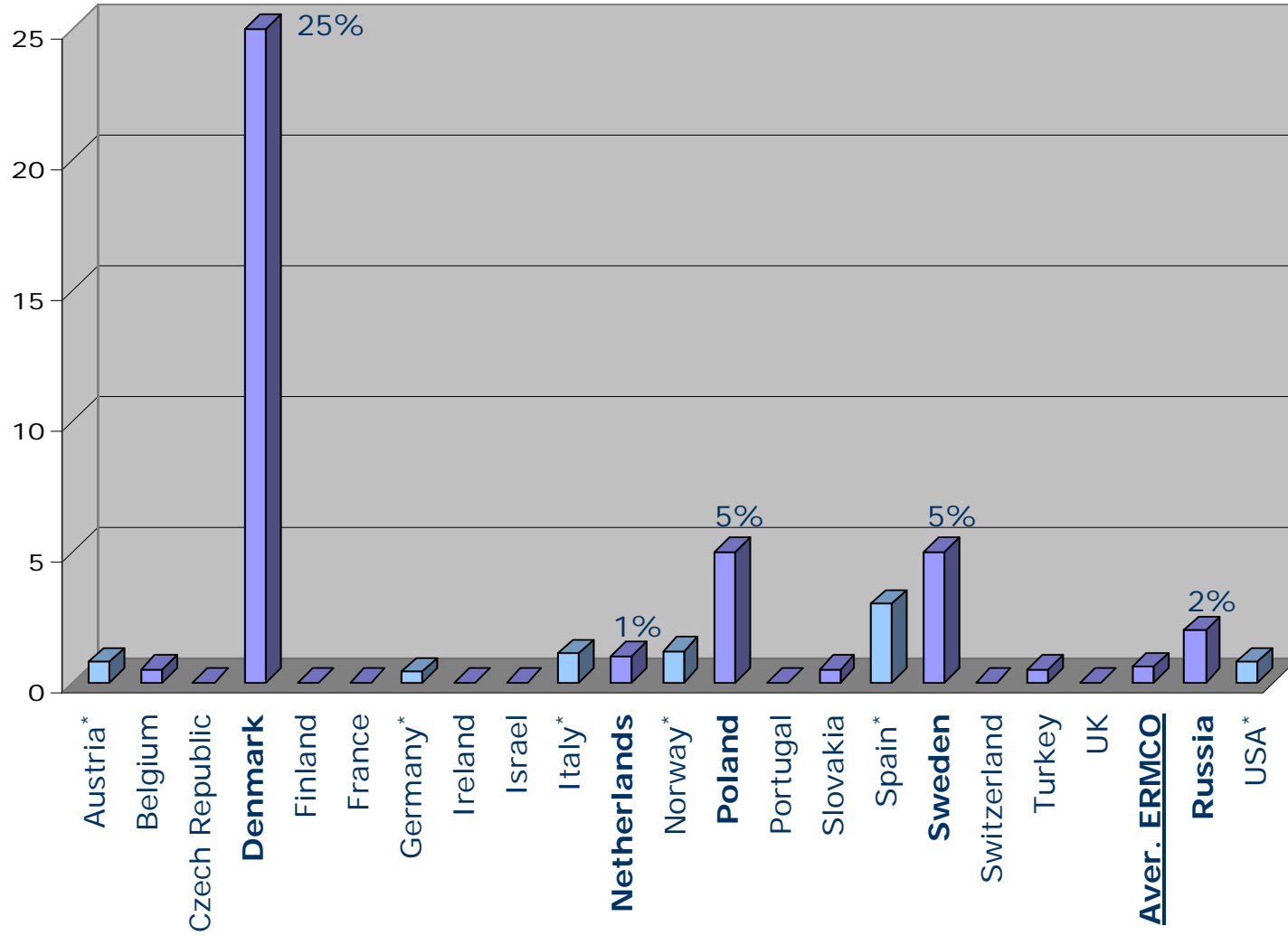


S1 (10 - 40 mm)
S2 - S3 (50 - 150 mm)
S4 - S5+ (160 - >220 mm)
SCC

source: ERMCO statistics 2000 - 2004  
(\* ) Only a limited number of countries  
contributed to the statistics 2000 - 2002

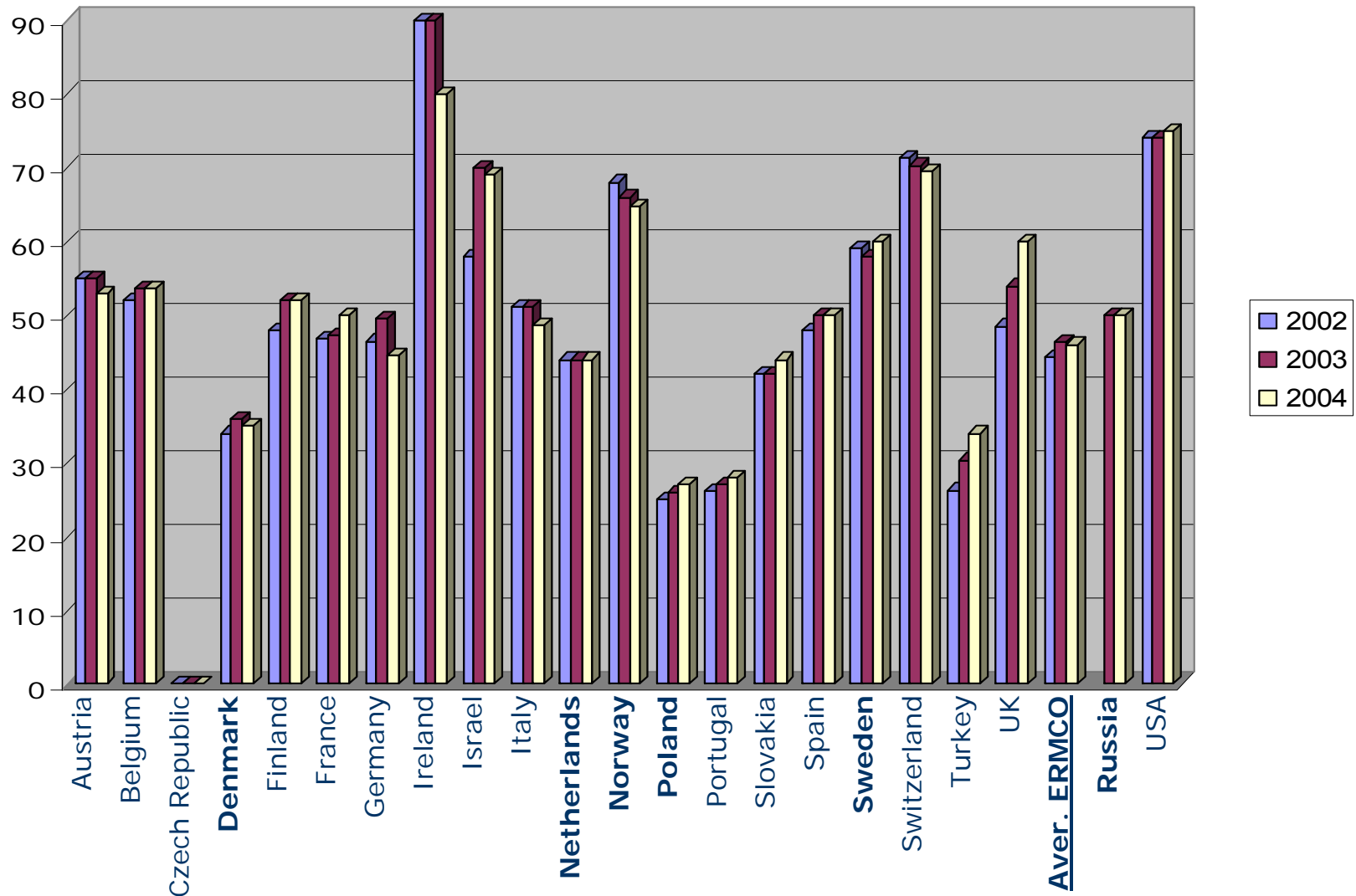


# SCC in Readymix Concrete [%]





# Cement sales to Readymix Concrete [%]







# RM vs. Precast -Where are the differences?





## SCC - Specific Properties

SCC has specific fresh properties different from normal concrete. These properties need to be additionally defined and controlled.

	covered by EN 206-1
Slump flow	S5(+) or F6(+)
Viscosity	✘
Passing ability	✘
Segregation resistance	✘

- ✘ EN 206 can not be used for SCC on site where the purchaser must specify the fresh properties of SCC.
- ✘ **It was this that lead to a European industry initiative to produce new SCC Guidelines.**





# The European Guideline for SCC





# Why European Guidelines for SCC?

## **Concrete purchasers need**

- ▶ confidence in the Engineering properties
- ▶ a Specification against which to purchase

## **Users need advise**

- ▶ on formwork and site preparation
- ▶ on acceptance criteria, placing and finishing

## **The European Concrete Industry needs**

- ▶ harmonised specifications
- ▶ harmonised test methods



## Primary

- ▶ Specification (presented in CEN format)
- ▶ Supporting test methods (in CEN format)
- ▶ Advice to users
- ▶ Engineering properties

## Secondary

- ▶ Mix design and constituents
- ▶ Advice to producer
  - ▶ Ready-mixed
  - ▶ Precast



# European Guideline for SCC - The Content

- ▶ **Terms and definitions**
- ▶ **Engineering properties**
- ▶ **Specifying SCC for ready-mixed & site mixed concrete**
- ▶ **Constituent materials**
  - ▶ Mix composition
- ▶ **Production of ready-mixed and site mixed SCC**
- ▶ **Site requirements and preparation**
- ▶ **Placing and finishing on site**
  - ▶ Precast concrete products
- ▶ **Appearance and surface finish**



# SCC - Views and (local) Regulations

What is Self compacting Concrete ... ?





# SCC - Views and (local) Regulations

## **wide difference in opinions**

- ▶ Slump flow: min 500 - 550 - 650 - 700 mm
- ▶ High or low viscosity
- ▶ High / low finer
- ▶ No /some segregation
- ▶ No blocking / no requirements

## **Increasing number of local regulations**

- ▶ Austria, Germany, Italy, Netherlands, Norway, Sweden, UK ...
- ▶ EFNARC SCC Guideline ...



## SCC - Engineering Properties (1)

At similar strength **SCC and vibrated concrete have comparable properties**

- ▶ **Compressive strength** of SCC could be slightly higher at same w/c-ratio.
- ▶ **Tensile strength** assume to be the same as a normal concrete with similar volume of paste.
- ▶ **E-value** could be lower due to higher amount of paste but covered by safety assumption in EN 1992-1.



- ▶ **Creep coefficient** may be expected to be higher due to higher amount of paste but covered by safety assumption in Eurocode 2.
- ▶ **Shrinkage** may be expected to be higher due to higher amount of paste but covered by safety assumption in Eurocode 2.
- ▶ **Coefficient of thermal expansion** assumed to be the same as stated in EN 1992-1-1.
- ▶ **Bonding properties** generally enhanced with SCC but Eurocode should be used.







## SCC - Engineering Properties (3)

- ▶ **Fire resistance** is similar to normal concrete.
- ▶ **Durability** may be expected to be higher due to lack of shortcomings (honeycombing, bleeding, etc.).

**Where** the value and/or the development of a **specific concrete property** with time **is critical, tests should be carried out** taking into account the exposure conditions and the dimensions of the structural member.





# European funded Project: "TESTTING SCC"



"Measurement of properties of fresh self-compacting concrete"

**Aim:** to find tests which identify the three key fresh properties of SCC, filling ability, passing ability and segregation resistance on a scientific base.

**Participants:**

**ACM Centre, University of Paisley, UK.**

Dansk Beton Teknik A/S (DBT)

University College London (UCL)

Swedish Cement and Concrete Research Institute (CBI)

University of Stuttgart (IWB)

Technische Universiteit Delft (TUD)

Betongindustri AB (BTI)

GTM Construction (GTM)

Universiteit Gent (RUG)

The Icelandic Building Research Institute (IBRI)

John Doyle Construction (JDC)

SP Swedish National Testing and Research Institute (SPI)



## Test Methods & Specifications / Classes

**SF**

Flow (Slump Flow)

**VF**

Viscosity (V-Funnel)

**PA**

Passing Ability (L-Box)

**SR**

Segregation Resistance (Sieve Stability)

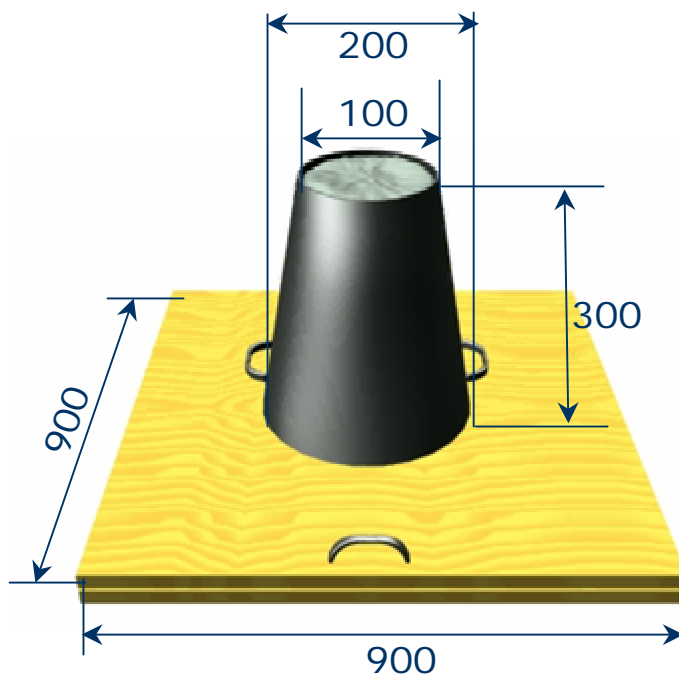


# SCC - Flow (1)

## SF

### Flow (Slump Flow)

class	Slump Flow
SF1	550 - 650 mm
SF2	660 - 750 mm
SF3	760 - 850 mm
target value	$\pm 80$ mm of target value





## SCC - Flow (2)

### SF1 (550 - 650 mm)

- ▶ slightly or non-reinforced structures that are cast from the top with free displacement from the delivery point (e.g. housing slabs)
- ▶ casting by a pump injection system (e.g. tunnel linings)
- ▶ sections with limited horizontal flow (e.g. piles, deep foundations)

### SF2 (660 - 750 mm)

- ▶ is suitable for many normal applications (e.g. walls, columns)

### SF3 (760 - 850 mm)

- ▶ typically with a small maximum size of aggregates (< 16 mm)
- ▶ used for vertical applications in very congested structures, structures with complex shapes, or for filling under structures

SF3 will often give better surface finish than SF 2, but segregation resistance is more difficult to control.





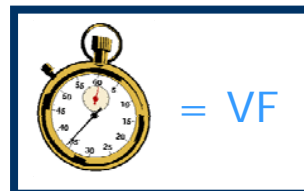
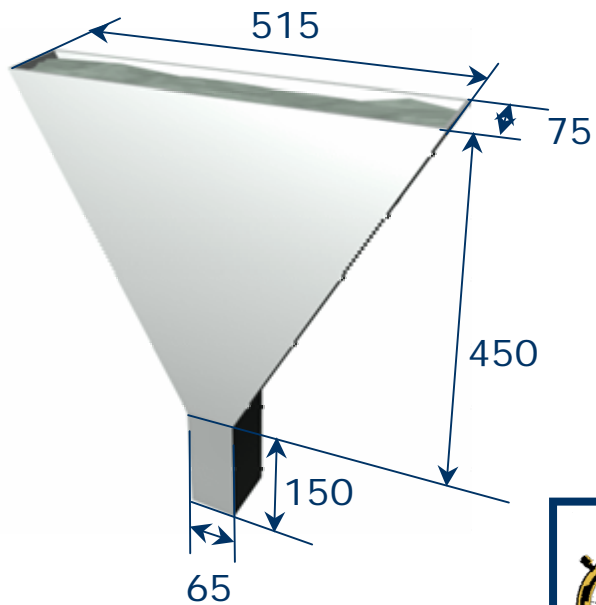
# SCC - Viscosity (1)

VF

VS

Viscosity (V-Funnel) /  $T_{500}$

class	V-Funnel	$T_{500}$
VF1/VS1	$\leq 8$ s	$\leq 2$ s
VF2/VS2	9 - 25 s	$> 2$ s
target value	$\pm 3$ s of target value	-





## SCC - Viscosity (2)

Viscosity should be specified only in special cases.

VF1/VS1 ( $\leq 8$  s /  $\leq 2$  s)

- ▶ good filling ability even with congested reinforcement
- ▶ capable of self-levelling and generally has the best surface finish
- ▶ more sensitive to suffer from bleeding and segregation

VF2/VS2 (9-25 s /  $> 2$  s)

- ▶ no upper class limit
- ▶ more likely to exhibit thixotropic effects (limit formwork pressure)
- ▶ improving segregation resistance
- ▶ Negative effects regarding surface finish (e.g., blow holes)
- ▶ sensitivity to stoppages or delays between successive lifts



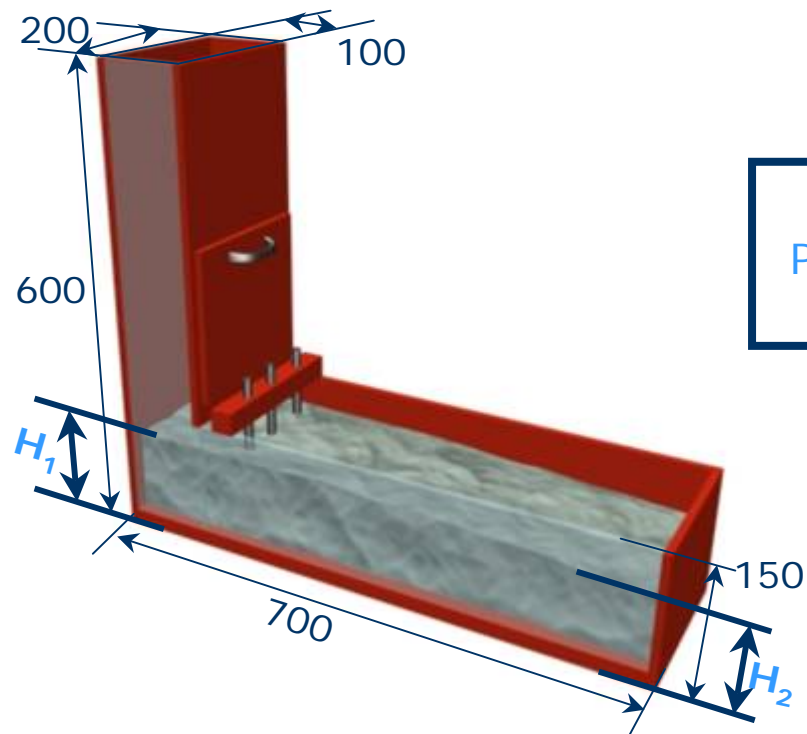


# SCC - Passing ability (1)

## PA

### Passing Ability (L-Box)

class	Passing Ability
PA1	$\geq 0.8$ with 2 rebars
PA2	$\geq 0.8$ with 3 rebars





## SCC - Passing ability (2)

Defining dimension: the smallest gap (confinement gap) through which SCC has to continuously flow to fill the formwork.

PA1 ( $\geq 0.8$  with **2** rebars)

- ▶ structures with a gap of 80 mm to 100 mm
- ▶ e.g. housing, vertical structures

PA2 ( $\geq 0.8$  with **3** rebars)

- ▶ structures with a gap of 60 mm to 80 mm
- ▶ e.g. civil engineering structures

Thin slabs with gap  $> 80$  mm and other structures with gap  $> 100$  mm  
 $\Rightarrow$  **no passing ability** is required.





# SCC - Segregation Resistance (1)

## SR

### Segregation Resistance (Sieve Stability)

class	Segregation Resistance
SR1	$\leq 20 \%$
SR2	$\leq 15 \%$



$$SR = \frac{M_2}{M_1 + M_2}$$





## SCC - Segregation Resistance (2)

Segregation resistance becomes an important parameter with higher slump-flow classes and/or the lower viscosity class, or if placing conditions promote segregation.

### SR1 ( $\leq 20\%$ )

- ▶ for thin slabs and for vertical applications with a flow distance of less than 5 metres and a confinement gap greater than 80 mm.

### SR2 ( $\leq 15\%$ )

- ▶ vertical applications, flow distance  $> 5$  metres with confinement gap  $> 80$  mm in order to take care of segregation during flow.
- ▶ for tall vertical applications with confinement gap  $< 80$  mm if flow distance is  $< 5$  metres.

- ▶ If flow is  $> 5$  metres (confinement gap  $< 80$  mm) a SR target value  $\leq 10\%$  is recommended.





## SCC - How to specify (1)

SCC will normally be specified as a **prescribed** or **proprietary** concrete.

- ▶ **Prescribed concrete** is most suitable if specifier and producer/ user are the same party, e.g. in **site mixed concrete** or **Precast** industry.
- ▶ For **Ready-mixed industry** the **proprietary concrete** (focuses on the performance) is preferred, due to clear acceptance criteria.
- ▶ Essential for the **purchaser** and **producer to** discuss and define SCC characteristics before starting the project.
- ▶ **Specifier** should not develop the SCC and specify the mix proportions to the producer - if so, one can not also specify fresh or hardened concrete properties.



## SCC - How to specify (2)

Specify SCC as **proprietary** concrete:

- ▶ In accordance with EN 206
  - ▶ Strength class
  - ▶ Exposure class
  - ▶ Limiting values (max. w/c-ratio, min. cement content, etc.)
  - ▶ Aggregate size  $D_{\max}$
  - ▶ Chloride class
  
  - ▶ SF class or target value
  
- ▶ In accordance with European Guideline SCC (- only if specifically needed)
  - ▶ VF class or  $T_{500}$  value
  - ▶ PA class or target value
  - ▶ SR class or target value

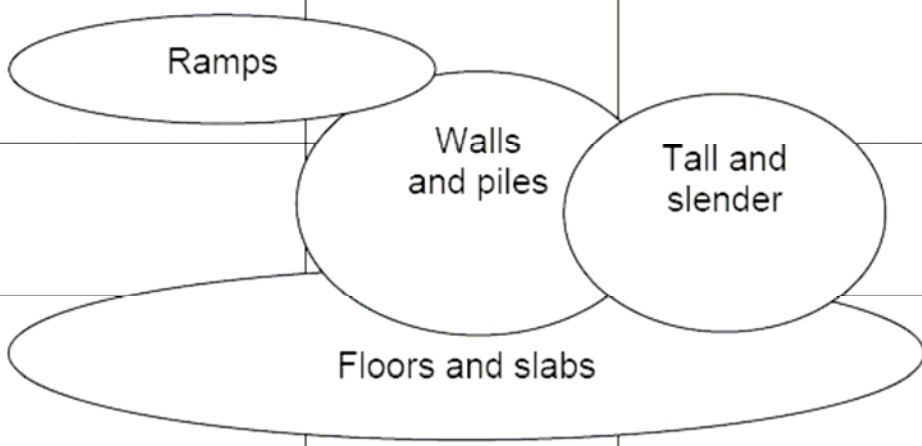


## SCC - How to specify (3)

Passing ability, viscosity and segregation resistance should only be specified if specifically needed.

- ▶ If there is little or no **reinforcement**, there may be no need to specify **passing ability**.
- ▶ **Viscosity** may be important for good **surface finish** or **dense reinforcement** but should not be specified in most other cases.
- ▶ **Segregation resistance** is important with higher fluidity and lower viscosity SCC but if specified, class 1 has been shown to be adequate for most applications.

## By Application

Viscosity				Segregation resistance/ passing ability
VS 2 VF 2				Specify passing ability for SF1& 2
VS 1 or 2 VF 1 or 2 or a target value.				Specify SR for SF 3
VS 1 VF 1				Specify SR for SF 2 & 3
	SF 1	SF 2	SF 3	
	Slump-flow			





## SCC - How to develop and produce (1)

- ▶ The **constituent materials** for SCC are the same as those used in traditional vibrated concrete conforming to EN 206-1.
- ▶ The requirements for individual constituents are covered by European standards.
- ▶ To ensure uniform and consistent performance for SCC, **additional care** is needed in initial selection and continual monitoring for uniformity of incoming material.
- ▶ Control of the constituent materials needs to be **increased and the tolerable variations restricted**, so that daily production of SCC is within specification without testing/adjusting every batch.





### Robustness in the fresh state

- ▶ Any variation in the uniformity of the constituents can result in a lack of filling/passing ability or lead to segregation.
- ▶ Most variability can be equated to a **change in water demand**, (changes in moisture content of the aggregates, changes in grading/specific surface).
- ▶ Well designed SCC has acceptable tolerance to daily fluctuations in these parameters ("**robustness**").
- ▶ Control by good practice in sourcing and handling, by appropriate content of the fine powders and/or by **use of a VMA**.
- ▶ A robust SCC can typically accept a **5 to 10 litre/m<sup>3</sup> change** in water content without falling outside the specified classes



# SCC - How to develop and produce (3)

## Quality assurance

- ▶ Equipment, operation and materials should be controlled under a Quality Assurance scheme. The producer should be accredited to ISO 9001 or equivalent.
- ▶ Personnel need adequate training prior to production from a person with experience of SCC. Training includes observing trial batches being produced and tested.
- ▶ Aggregates should be evaluated each production day before production. Visual checks on each delivery of aggregate. Any noticeable change should be evaluated prior to accepting.
- ▶ The moisture content of aggregates should be continuously monitored and the mix adjusted to account for any variation.



# SCC - How to develop and produce (4)

## Production process

- ▶ SCC can be produced with any efficient concrete mixer (paddle mixers, free fall mixers and truck mixers) but force action mixers are generally preferred.
- ▶ Experience shows that mixing time may be longer due to reduced frictional forces and to fully activate the admixtures.
- ▶ Preliminary trials should be carried out (> half the capacity of the mixer) to ascertain the efficiency of the mixer and the optimum sequence for addition of constituents.
- ▶ A high paste content and the fluidity of SCC can make it more difficult to achieve a uniform mix. (formation of unmixed "balls" of constituents - not easy to break down).



## SCC - Transport and Delivery (1)

- ▶ Every load should be tested for slump-flow until consistent results are obtained.
- ▶ Other tests to confirm compliance with the contract specification.
- ▶ Every batch should be visually checked before transportation.
- ▶ Production capacity of the plant, journey time and placing capability at site need to be balanced to ensure that SCC can be placed without a break in supply.
- ▶ Production stops can result in thixotropic gelling of concrete already placed.



### Site acceptance

- ▶ For RM concrete, a standardised procedure for receiving and accepting the SCC at site should be agreed and documented.
- ▶ Every batch of SCC delivered should be tested for slump-flow until uniformity of supply is confirmed.
- ▶ Visual assessment by a competent person is then normally sufficient unless a batch is considered to be marginal.
- ▶ Annex A sets minimum rates of testing for the fresh properties of SCC.
- ▶ EN 206-1 gives normal rates of testing for hardened concrete properties.



## Quality assurance

It is essential that the site personnel have been trained/ instructed in the specific requirements for placing this type of concrete. Particular emphasis should be placed on the following:

- ▶ Effect of vibration on mix stability
- ▶ Rate of placing
- ▶ Effect of a break/stoppage during placing
- ▶ Actions to be taken if a break/stoppage occurs
- ▶ Observation for blockages, segregation or air release
- ▶ Requirements for placing by pump, skip or chute, including positioning to induce flow
- ▶ Finishing top surfaces and curing.

## Formwork

- ▶ Unusual or complex shapes can be produced that would not be possible with vibrated concrete.
- ▶ High flowability of SCC can result in flotation of item not securely fixed.
- ▶ Fixing and sealing the formwork to the base needed where uplift could be a problem.



## Formwork

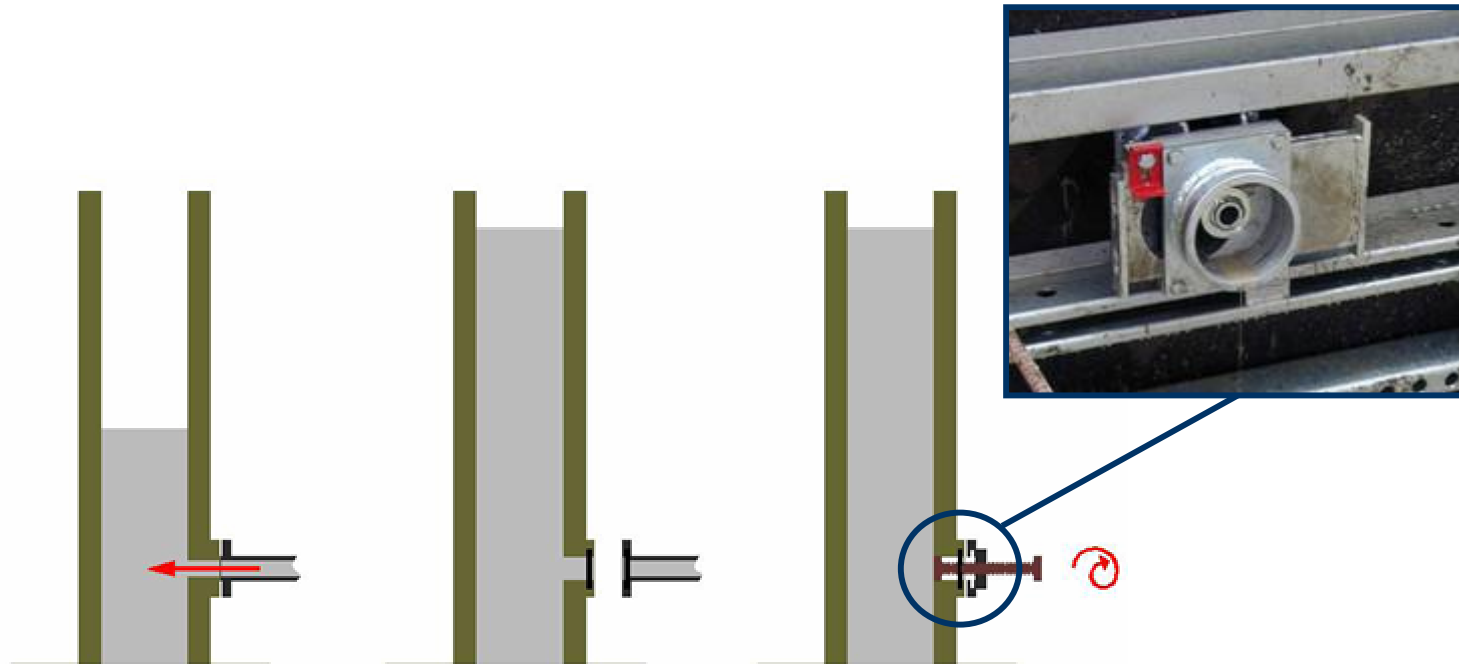
- ▶ Leakage at joints can occur, however SCC generally leaks less than concrete that has to be vibrated.
- ▶ full hydrostatic concrete pressure should be assumed when using SCC to ensure that the formwork cannot deform during placing.
- ▶ Caution: SCC produces a very high quality finish giving a mirror copy of the formwork.





## Formwork

- ▶ Novel formwork e.g. with magnetically attached shape formers are possible.
- ▶ Novel methods of placing concrete including pumping bottom up are possible.





### Placing procedure

- ▶ Arrange reinforcement and formwork as planned, free of water or debris.
- ▶ Release SCC into the formwork in relation to the density of reinforcement, the concrete's flow characteristics and to the potential for entrapment of air. Avoid free fall.
- ▶ A reasonable length of flow helps excess air to escape. Flow length  $> 10$  metres may create a greater risk of dynamic segregation or void formation.
- ▶ Too fast vertical casting rate may cause an increased number of air voids in the concrete and blowholes on the surface.
- ▶ The casting process should be continuous and without interruption to maintain flow and reduces surface marks and colour variation.

## Finishing

- ▶ Slabs require a lower SF class than SCC for walls and columns which can make the concrete feel sticky and difficult to finish.
- ▶ Vibrating floats and light vibrating screeds have proved to be effective (Not for inclining slabs or risk of aggregate segregation).
- ▶ Levelling of slabs is best with a skip float. Steel floats function better than those of wood or polyurethane cell foam.





### Curing

- ▶ Curing is important for all concrete especially for the top-surface.
- ▶ Initial curing should therefore commence as soon as practicable after placing and finishing.
- ▶ SCC can dry quickly because of
  - ▶ a increased quantity of paste
  - ▶ a low water/fines ratio
  - ▶ a lack of bleed water at the surface

## Improving the finish of SCC - Annex C

Type of defect	Primary reasons	Practical reasons	How to prevent or correct
Colour variations	along the surface differences between batches	<ul style="list-style-type: none"> <li>• too low temperature</li> </ul>	<ul style="list-style-type: none"> <li>• maintain concrete and in-form temperature during winter conditions</li> </ul>
		<ul style="list-style-type: none"> <li>• too high slump-flow, too low viscosity</li> </ul>	<ul style="list-style-type: none"> <li>• increase viscosity by increasing fines or consider using VMA</li> </ul>
		<ul style="list-style-type: none"> <li>• retarding effect of admixture or release agent</li> </ul>	<ul style="list-style-type: none"> <li>• careful selection of admixtures to open-life requirement</li> <li>• reduce water content or reduce plasticiser addition rate</li> <li>• consider using a mild accelerator</li> <li>• use geo-textile form liner</li> </ul>
		<ul style="list-style-type: none"> <li>• changes in rate of pour</li> </ul>	<ul style="list-style-type: none"> <li>• continuous casting</li> </ul>
		<ul style="list-style-type: none"> <li>• plastic curing membrane irregularly in contact with concrete surface</li> </ul>	<ul style="list-style-type: none"> <li>• ensure consistent contact</li> </ul>
		<ul style="list-style-type: none"> <li>• surface-dry timber moulds</li> </ul>	<ul style="list-style-type: none"> <li>• wet mould before casting</li> <li>• preferably use coated form-face</li> </ul>
<p><b>Physical reasons:</b> retarding or staining effect caused by oil, admixture etc. too high plastic viscosity or yield stress</p>			





# The European Guideline for SCC





# SCC - will be standardised



## CEN TC 104/SC1

"Concrete - Specification, performance, production and conformity"

has decided in November 2005 to run two working groups on standardisation of SCC:

### **TG 8:**

Standardisation of test methods in the EN 12350 Series:

- Slump flow and  $T_{500}$
- Sieve segregation
- V-funnel
- L-box
- J-ring

### **TG 16: Provisions for SCC**

to prepare a report on provisions regarding the requirement for SCC (testing, product requirement, execution requirements) in the CEN-member countries ➔ relevant parts may be introduced into EN 206.





# European Guideline for SCC - Availability

The European Guideline SCC will not be printed, it is available for free Download:



<p><a href="http://www.efca.info">www.efca.info</a> <a href="http://www.efnarc.org">www.efnarc.org</a> <a href="http://www.ermco.org">www.ermco.org</a> <a href="http://www.cembureau.be">www.cembureau.be</a> <a href="http://www.bibm.org">www.bibm.org</a></p>	<p><a href="http://www.anfah.org">www.anfah.org</a></p>
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Thank you for you attention

