



norden

Nordic Innovation Centre

September 2006

Nordic SCCNet

Nordic network for RTD on Self Compacting Concrete

- Benefits, costs and challenges
- A Nordic Network with the objective to exchange results and knowledge in order to establish an improved basis for use of Self Compacting Concrete
- More information at www.nordicscc.net

Participants:

Denmark



**DANISH
TECHNOLOGICAL
INSTITUTE**

Teknologisk Institut, Beton
Anette Berrig

BYG·DTU



**BYG.DTU, Danmarks Technologiske
institut**
Mette Geiker



BETON

DK-Beton-gruppen
Harald Johannsen

Finland

FINNSEMENTTI

Finnsementti Oy
Jorma Virtanen

LOHJA RUDUS

Lohja Rudus Oy Ab Development
Mirva Vuori

PARMA



Parma Oy
Jouni Punkki

VTT Building and Transport
Markku Leivo

Iceland



Iceland Building Research Institute
Olafur Wallevik



Steypustöðin ehf
Kai Westphal

Norway



Degussa Construction Chemicals Norway
Lars Busterud



NORCEM A.S
Nina Linn Gundersen



Norbetong AS
Bård Pedersen



SINTEF Building and Infrastructure Concrete
Tor Arne Hammer (project leader)



Skanska Norge AS
Sverre Smeplass



Veidekke ASA
Alf Egil Mathisen

Sweden



Cement och betong Institutet
Peter Billberg



Betongindustri AB
Mats Emborg



Cementa
Hans-Erik Gram



Vägverket Produktion
Thomas Österberg

Title: Nordic Network for RTD on Self Compacted Concrete (Nordic SCCNet)		
Nordic Innovation Centre (NICE) project number: 03037		
Author: Tor Arne Hammer		
Institution: SINTEF Building and Infrastructure		
Abstract: Self Compacting Concrete (SCC) is a collective term for concrete with very high flowability, and which may be placed without addition of compacting energy, e.g. by poker vibrators. Thus, use of SCC contributes potentially to increased productivity (e.g. faster casting operation and with less workers) and improved working environment (no use of heavy, vibrating and noisy compacting tools). Some studies claim also better durability and surfaces. The potential has been demonstrated in a number of studies in several countries. Still, the market share of SCC is generally very low. The project is a network with the aim to exchange results and knowledge in order to establish an improved basis for use of Self Compacting Concrete (SCC). It includes identification of obstacles, and procurement and spread of knowledge about how to overcome them. The work has achieved this aim by bi-annual assemblies with the 18 participants covering the national R&D projects on SCC, as well as the actors in the building and construction market; owners, consultants, material suppliers, contractors and research institutes/universities discussing specific topics of interest. The new information and knowledge gained through the assemblies were spread by: • The participants bringing new knowledge, research approaches and the like, back to the national R&D projects in order to strengthen the R&D in the projects • WEB-site • Liaisons established with national and international committees • Presentations at National and Nordic concrete days • The workshop "SCC – Vision and Reality" at Kastrup 19 June 2006, with nearly 100 participants from the Nordic building industry		
Topics/NICE Focus Area: Innovative Construction		
ISSN:	Language: English	Pages:
Key words: Network, research and development, self compacting concrete		
Distributed by: Nordic Innovation Centre Stenbergsgata 25 NO-0170 Oslo Norway		Contact person: Tor Arne Hammer SINTEF Building and Infrastructure NO-7465 Trondheim Norway E-mail: Tor.Hammer@sintef.no Phone: +47 - 73 59 68 56 Mobile: +47 - 930 58 686

Executive summary

The purpose of the project was to:

- Exchange results and knowledge in order to establish an improved basis for use of Self Compacting Concrete (SCC)
- Identify obstacles and provide and spread knowledge about how to overcome them

The work has achieved this aim by:

Bi-annual assemblies with the 18 participants covering the national R&D projects on SCC, as well as the actors in the building and construction market; owners, consultants, material suppliers, contractors and research institutes/universities discussing specific topics of interest.

The new information and knowledge gained through the assemblies were spread by:

- The participants bringing new knowledge, research approaches and the like, back to the national R&D projects in order to strengthen the R&D in the projects
- WEB-site
- Liaisons established with national and international committees
- Presentations at National and Nordic concrete days
- The workshop "SCC – Vision and Reality" at Kastrup 19 June 2006, with nearly 100 participants from the Nordic building industry

Method

Self Compacting Concrete (SCC) is a collective term for concrete with very high flowability, and which may be placed without addition of compacting energy, e.g. by poker vibrators. Thus, use of SCC contributes potentially to increased productivity (e.g. faster casting operation and with less workers) and improved working environment (no use of heavy, vibrating and noisy compacting tools). Some studies claim also better durability and surfaces. The potential has been demonstrated in a number of studies in several countries. Still, the market share of SCC is generally very low.

- Therefore, the project started with a study in order to find the main reasons for this and identify the obstacles to overcome. This was done by the use of a questionnaire among the participants, requesting for their opinion about reasons and obstacles.
- Then, the most important reasons and obstacles were discussed in the bi-annual assemblies, and actions to overcome obstacles were presented and made accessible in an internet based project base
- As one obstacle was related to lack of guidelines and norms, liaisons were established with relevant international committees working with guidelines and standardisation, both in order to influence their work and to make information accessible to the participants. Key persons in such committees were invited to assemblies (if not SCCNet member)
- Main results and examples how to overcome obstacles were presented at the workshop "SCC – Vision and Reality" at Kastrup 19 June 2006, with nearly 100 participants from the Nordic building industry

Main results, conclusions and need of further work

- Use of SCC improves potentially productivity and working environment
- SCC has a potential to replace the major part of common vibrated concrete
- Main obstacles for increased market share of SCC is related to higher material cost, mix design/robustness regarding workability and segregation and lack of guidelines

- Since the major volume of concrete is used in buildings with less demanding performance requirements, and thus with relatively low price, it is necessary to develop compliant SCC with acceptable material cost. This has shown to be a challenging task, first of all because of the cost of means needed to achieve sufficient stability against segregation of SCC, but also because the technology for production of such “cheap” SCC is young and not sufficiently spread. However, mix design guidelines for such SCC is now available, but more RTD work seems necessary in order to improve the robustness of such concretes
- The acceptable material cost of SCC is strongly influenced by the economical benefits of using SCC. It has been demonstrated that savings related to e.g. less repair, faster casting and less labour may be higher than the additional material cost. More studies are however needed
- A number of the Nordic SCCNet members have been directly or indirectly active in international committees working with guidelines and standards for SCC. This has contributed to reflect Nordic attitude which make the Nordic countries even better prepared for such standards
- In general, the network contributed to make contacts between participants which may be utilised in future projects. The participants decided to continue Nordic SCCNet, financed by own money

1. BACKGROUND	1
2. OBSTACLES FOR SCC OBTAINING AN INCREASED MARKET SHARE	2
2.1 Cost – benefit	2
2.2 Lack of robustness and confidence	2
2.3 Lack of guidelines and norms	3
3. INTERNATIONAL STANDARDISATION WORK.....	4
4. MAIN RESULTS	4

APPENDICES:

Presentations at the workshop “SCC – Vision and Reality”

- Introduction and status of use and R&D in the Nordic countries
- Guidelines / Quality Control
- Mix Design
- Economy / Benefits / Environment
- Production / Execution

1. BACKGROUND

Self Compacting Concrete (SCC) is a collective term for concrete with very high flowability, and which may be placed without addition of compacting energy (e.g. by poker vibrators). Thus, use of SCC contributes potentially to increased productivity (e.g. faster casting operations and with less workers) and improved working environment (no use of heavy, vibrating and noisy compacting tools). Some studies claim also better durability and surfaces. The potential has been demonstrated in a number of studies in several countries. Still, the market share of SCC is generally very low.

Therefore, the main task of the project was to find the main reasons for the low market share. It includes identification of the obstacles, and to procure and spread knowledge about how to overcome them, in order to establish an improved basis for use of SCC.

Obstacles were identified by the use of a questionnaire among the 18 participants of the project, requesting for their opinion about reasons and obstacles. Then, the most important reasons and obstacles were discussed in bi-annual assemblies. The participants covered the Nordic R&D projects on SCC, as well as the actors in the building and construction market; owners, consultants, material suppliers, contractors and research institutes/universities.

As one obstacle was related to lack of guidelines and norms, liaisons were established with relevant international committees working with guidelines and standardisation, both in order to influence their work and to make information accessible to the participants. Key persons in such committees were invited to assemblies (if not SCCNet member).

Main results of the work and examples how to overcome obstacles were presented at the workshop, organised by Nordic SCCNet, "SCC – Vision and Reality" at Kastrup 19 June 2006, with nearly 100 participants from the Nordic building industry

Other tools to procure and spread knowledge were:

- The participants bringing new knowledge, research approaches and the like, back to the national R&D projects in order to strengthen the R&D in the projects
- WEB-site: www.nordicscc.net
- Presentations at National and Nordic concrete days

2. OBSTACLES FOR SCC OBTAINING AN INCREASED MARKET SHARE

Possible obstacles were discussed among the participants and in other forums of SCC. A questionnaire among the participants was also used. The questions were: What do you think are the main obstacles for an increased market share of SCC, and how do you think they can be forced?

In general, the discussions revealed that mix design of SCC varied between the countries, as result of different part materials, but also different mix design approaches. For instance, Swedish SCC tends to contain more fines than Danish and Norwegian SCC. The discussions revealed also differences in the definition of SCC between countries, but also related to application: In Denmark SCC is all concrete cast without use of compaction tools, the main application being slabs. Slabs are cast without compaction tools in other countries also, but the flow of the concrete is still below the defined minimum values for SCC (e.g. minimum slumpflow of 600 mm). Accordingly, the difference in definition contributes also to the difference in market share between the countries.

The results of the discussions may be divided in three groups:

2.1 Cost – benefit

SCC costs more than the “competing” NCC, and it has not been sufficiently documented that savings in less workers, faster casting, less repair, etc., as well as improved working environment is more than the additional cost. The acceptable additional cost of SCC is strongly influenced by the economical benefits of using SCC.

The additional cost has two factors:

1. Cost of means needed to achieve sufficient stability against segregation of SCC. It may include investments in e.g. extra silos for fine sands and or fines
2. Riskiness for the concrete producer. Concrete producers experience higher risk of return batches and more following up work

Also, it was not clear which actor in the value chain that profits the most, and thus, should be the target for marketing SCC

2.2 Lack of robustness and confidence

The experience reveals that the flowability and segregation resistance of SCC as used, are sensitive to natural variations in the composition of the SCC (e.g. moisture

content and grading of aggregates), as well as to common variations in transportation and casting procedures (temperature, time, delayed admixture addition, etc.). This appears to be both an economical and technical question. Economical, because the concrete producers like to use part materials on silo intended for NSC, which not necessarily are suitable for SCC. Technical, because of lack of knowledge about the influence of part materials and admixtures on the production properties.

The major volume of concrete is used in buildings with less demanding performance requirements, which means that concrete with relatively low price is used. Consequently, it is necessary to develop compliant SCC with acceptable additional cost. This has shown to be a challenging task, first of all because of the cost of means needed to achieve sufficient stability against segregation of SCC (see above), but also because the technology for production of such “cheap” SCC is young and not sufficiently spread.

2.3 Lack of guidelines and norms

Lack of guides for proportioning of “cheap” SCC was another obstacle mentioned, and also lack of consistent test procedures for compliance control, as well as casting procedures for various applications. Regarding the latter, it seems sensible to look at the relationship between type of object/application, casting technique and fresh SCC properties. Work is being performed with the aim to simulate flow numerically, based on the rheological properties of the concrete and the boundary conditions. This will be a valuable contribution to the work in preparing a guideline for production.

Testing of the fresh SCC and casting of specimens are not standardised, and SCC is not mentioned in any CEN-standard to day. This constitutes a potential formal conflict because the existing standards require compaction, which shall not be used on SCC. A proposal for such SCC test methods was prepared within the NICE project “Test methods for SCC”. The SCCNet acted as reference group and agreed with the proposal, except for the proposed test for segregation resistance.

A commonly accepted segregation test is still lacking. This is particularly unfortunate since resistance to segregation is as important as flowability, and thus, an important factor in the compliance control, also. At present, segregation resistance is often evaluated visually, which may lead to dispute between concrete producer and contractor on site.

Furthermore, the contractual situation of the trade between the concrete producer and the contractor is not clear: The new aspect using SCC is that the potential conflict in that the concrete producer is basically responsible for the compaction of the concrete, while the contractor is responsible for the quality of the final product.

3. INTERNATIONAL STANDARDISATION WORK

There are a number of international committees world wide dealing with SCC. A list is given in www.nordicscc.net. One or more SCCNet members participate in the committees.

The CEN-standards shall be used in Europe. As previously mentioned, SCC is not mentioned in any CEN-standard to day. A CEN-committee (CEN TC 104/SC1) is being established with participants from Nordic SCCNet also, in order to evaluate test methods for SCC.

The question is if SCC has properties that are in conformity with the design assumptions in the CEN-design standard (Eurocode 2). This regards particularly cases where SCC is produced without coarse aggregate.

Another important point is that the standards should regulate the trade between concrete producer and contractor. This is suggested in the on-going revision work of prEN 13670. Also, this standard will have an “Informative annex” describing placing and finishing of SCC. SCCNet communicates with the convener of this committee (Steinar Helland, Skanska).

“The Europe Guidelines for SCC” was prepared in 2005 by a group of European concrete organisations with participants from SCCNet. The document is considered as European consensus report on SCC, and basis for the future work on standardisation. The document can be downloaded from www.nordicscc.net.

4. MAIN RESULTS

Main results of the work and examples how to overcome obstacles were presented at the workshop “SCC – Vision and Reality” at Kastrup 19 June 2006, with nearly 100 participants from the Nordic building industry. There were 13 presentations on the five topics:

1. Status in the Nordic countries
2. Guidelines
3. Mix design
4. Benefits and
5. Production

The presentations are given in APPENDIX 1. The presentations were followed by four parallel workshop sessions where the technical topics were discussed more in detail, and conclusions reported in plenum.

The market share of SCC has increased in the last couple of years in Denmark and Sweden. The Danes claim approximately 25 % market share (but note definition differences as previously discussed), in prefabrication and ready mixed concrete in slabs, mainly. This is partly results of the still running joint industry project “SCC Konsortium”. The Swedes claim approximately 10 %, in prefabrication and in ready mixed concrete for housing, mainly. There are no major joint industry projects on SCC at the moment, but several smaller and local projects. The market share in the other countries is still below 2-3 %, and without optimistic prospects in the near future. Except that the Norwegians seem optimistic in that they started two joint industry projects a year ago, one with the ambiguous objective to increase the market share up to nearly 50 % in 5 years.

The presentations certainly confirm the potential of using SCC, both in savings due to less labour input and improved working environment. Moreover, calculations show that the savings may easily exceed the additional price of SCC. Used in floor, for instance, net savings of up to EUR 18/m² was shown. Also, there appears to be potentially further savings by utilizing the relationship between tailored concrete properties and new/improved production techniques.

Thus, since sufficient guidelines exist also (see e.g. www.nordicscc.net), the main remaining obstacle is the lack of robustness, and the challenge is how it can be forced without resulting in an unacceptable additional charge. This should be in focus in the further RTD-work on SCC.

It seems that the contractors are the main profiteers of using SCC. They may save money as result of less labour input and faster production, and their workers experience less health problems. It was also claimed that SCC sometimes is specified by the architect/building owner/consultant because of request for good surfaces and good working environment (note, however, that good surfaces can be obtained with NCC, too).

APPENDICIES

Presentations at the workshop
"SCC – Vision and Reality"

Introduction and status of use
and R&D in the Nordic countries

Nordic SCC-Net



DANISH
TECHNOLOGICAL
INSTITUTE

BYG•DTU



BETON

FINNSEMENTTI

LOHJA RUDUS



degussa.

creating essentials



SKANSKA

Skanska.com



Betongindustri
HEIDELBERGCEMENT Group



norden

Nordic Innovation Centre

Nordic SCCNet

Nordic SCCNet

The workshop is a part of the delivery from SCCNet

Intention of the workshop is to:

- exchange knowledge and experience in the Nordic countries
- inform about possibilities and benefits
- discuss obstacles and how to overcome
- inform were to find guides and solutions

Many thanks to

Jeanette von Mehren and Lars Nyholm Thrane, DTI,
for taking care of the practical part of the organising!



norden

Nordic Innovation Centre

Nordic SCCNet

SCCNet - time and budget

- Pre-project in fall 2002
- Summer 2003 - summer 2006
- Total budget is NOK 5 mill, 2.5 mill from NICE



Background

SCC contributes potentially to increased productivity and improved working environment.

Some studies claim also improved strength, durability and surfaces.

The potential has been demonstrated in a number of studies in several countries.

Still, the market share of SCC was generally very low.

WHY?

There was little co-operation and co-ordination within the Nordic countries, and activities were therefore partly overlapping and partly complementary.

This was demonstrated in a pre-project showing that focus varies between the countries, ranging from fundamental approaches on mix design and material models to applications and execution, but also that the topics are of common interest.



Objective and method

To exchange results and knowledge in order to establish an improved basis for use of SCC.

It includes identification of obstacles, and procurement and spread of knowledge about how to overcome them.

The work has achieved this aim by bi-annual assemblies with the 18 participants discussing specific topics of interest.

The participants cover the national R&D projects on SCC, as well as the actors in the building and construction market; owners, consultants, material suppliers, contractors and research institutes/universities



Method cont.

The new information and knowledge gained through the assemblies were spread by:

- The participants bringing new knowledge, research approaches and the like, back to the national R&D projects in order to strengthen the R&D in the projects
- WEB-site: www.nordicscc.net
- Liaisons established with national and international committees
- Presentations at National and Nordic concrete days
- The present workshop "SCC - Vision and Reality"



Method cont.

Questionnaire about obstacles was basis for identification of topics to be discussed.

The most important topics were found within:

- **Cost - benefit**
Higher concrete price than the "competing NCC"
Savings in less workers, faster casting, less repair
- **Lack of guidelines and norms**
Mix design
Production and compliance control
Casting procedures
- **Robustness**
Mix design to achieve acceptable properties
Production - relationship between type of object, casting technique and fresh SCC properties



Economy / Benefits / Environment

Benefits of use of SCC in common buildings/structures could be:

economical,
work environmental,
technical and
aesthetical.

Within these four groups some benefits are directly decisive for the choice of SCC, while others are "nice to have" (.

In addition, SCC is a "problem solver" offering easier casting of "complicated" structures or parts of structure."

Who are we going to convince?



Economy / Benefits / Environment

Economical benefits

Placement (faster casting and with less workers and tools as well as less workers reported sick)

Finishing (faster and with less workers and tools, as well as less need of self-leveling toppings)

Repair of casting defects (need of repair is eliminated or at least significantly reduced)

Also, as there in many regions are lack of workers and bad recruiting, SCC may be the way out.

Less sickness absence



Economy / Benefits / Environment

Work environmental benefits

Eliminated impact of lifting and carrying of compaction tools, on arms, shoulders and backs.

Less noise

Improved ergonomic and occupational safety makes the building industry more attractive regarding recruiting of workers.



norden

Nordic Innovation Centre

Nordic SCCNet

Economy / Benefits / Environment

Technical benefits

Some studies show that strength and durability of the building/structure is better than equivalent NCC.

This has been explained as result of less defects, better homogeneity (e.g. improved paste/aggregate phase and more even degree of compaction) and better paste/rebar bond.

However, all are of the "nice to have" kind and can hardly be used as main attraction for the choice of SCC?

May be more important: SCC is a "problem solver" offering easier casting of "complicated" structures or parts of structure."



Economy / Benefits / Environment

Aesthetical benefits

There is no doubt that SCC gives potentially better surfaces than NCC.

In most cases, this is a "nice to have benefit", but it can be used in a specification for special surfaces (note however that SCC is not a must to achieve special surfaces).



Nordic SCC Network Workshop

Marketing of SCC in Norway

Inge R. Eeg

Norcem AS

June 2006

Goal

- To increase the application of SCC in Norway from today's approx. 60`m<sup>3</sup>/year to 1000`m³/year
- Prefabricated elements: +/- 50% of all concrete except dry concrete (hollow core etc.)
- RMC: only project related

Aims:

- To establish confidence in successful concrete work with less flaws and improved durability.
- To obtain more aesthetic structures in terms of both surface quality and shape by means of slimmer and more densely reinforced concrete

Aims:

- To demonstrate a better overall economy for specific projects
- To demonstrate improvements in HES related questions
- To create acceptance among customers for improved product precision and quality

How?

- Demonstration of the SCC advantages for the dominating volume of "ordinary" structures (flooring, slabs, walls) and "common" concrete in selected projects
- Documentation of the profit by utilising SCC in selected projects

How?

- Establish a SCC marketing campaign;
 - Web site
 - Brochures / guidelines
 - Demonstrations / reference project
 - Documentation (HES, quality, profit)
 - Presentations / workshop

Web site
(Selvkomprimerendeбетong.no)

Project organisation

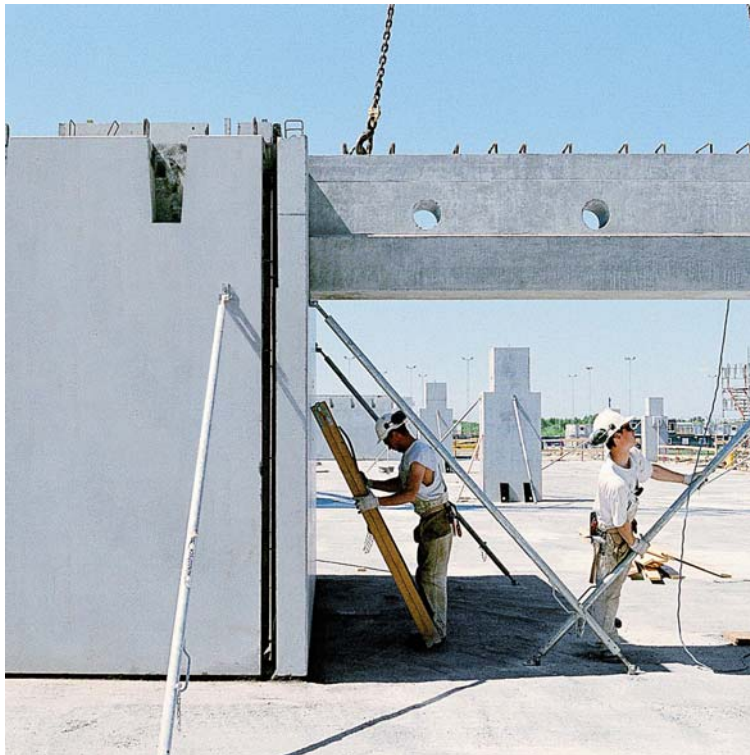
1. All participants (approx. 20 companies)
2. Steering committee (Norcem, Skanska, Veidekke, Unicon, Spenncon and The Norwegian Road Dept)
3. Project leader (Sintef)
4. Part project leaders / groups

Time frame and cost

- 2006 – 2009
- Approx 0,5 mill NOK / year
- Work contribution hours/yr (?)
- Material contribution m³/yr (?)

Nordic SCC Network Workshop

19 June 2006



Facts about the Consortium

- SCC-Consortium

- Established in 2003
- 3½ year innovation project.
- 17 companies and knowledge centres are participating
- Representing every stage of the value chain
- Activities continue until 2007
- The overall budget represents approx. DKK 20 million
- DKK 7,7 million contributed by the Danish Ministry of Science, Technology and Innovation

The Main Partners

- MT Højgaard a/s (Head of Steering Committee)
- Danish Technological Institute (Project manager)
- 4K Beton
- Aalborg Portland A/S
- Videometer A/S
- Betonelement A/S
- Informatics and Mathematical Modelling of the Technical University of Denmark

The Scope

- SCC the most used type of concrete in Denmark before 2008
- Improvement of the working environment
- Increased productivity
- A technology jump to the Danish Concrete Industry

Activities and Projects in the Consortium

Description

Floors

Prefabricated
elements

Civil
engineering

Activity

D1. Productivity and working environment

Projects

P1. Material
development

P2. The future
concrete
factory

P3. Use of SCC
and full scale
testing

Activity

D2. Communication and implementation

SCC-Consortium

■ SELF-COMPACTING CONCRETE SCC stands for Self Compacting Concrete. SCC was created in Japan at the end of the 1980s. Today, Denmark is the largest user of SCC relative to the total domestic consumption of concrete. SCC has excellent flow properties and can therefore be cast without the use of vibration or other mechanical influences. Less effort is therefore required, and the amount of noise produced is greatly reduced. SCC's advantages include a better working environment, better concrete quality, improved productivity, minimum need for levelling equipment, lighter work, less time consumption and a better overall economy. The flow properties are achieved by means of chemical admixtures and good mix design. SCC can be used both for casting in situ and for the production of precast concrete elements. ■ CONTACT Chairman of the SCC Consortium's Steering Committee Lars Gredsted, Division Manager MT Højgaard a/s +45 2270 9816 lag@mthojgaard.dk Head of the SCC Consortium Mette Glavind, Centre Manager Danish Technological Institute, Concrete +45 7220 2220 mette.glavind@teknologisk.dk For further information go to www.scc-konsortiet.dk	PARTICIPANTS ■ INDUSTRY 4K Beton A/S one of Denmark's largest manufacturers of ready-mix concrete, producing more than 500,000 cubic metres a year MT Højgaard a/s Denmark's leading industrial contractor, with 5,100 employees and an annual turnover of just under DKK 8 billion Aalborg Portland A/S Denmark's only cement manufacturer and the world's leading manufacturer and exporter of white cement Videometer A/S manufacturer of advanced vision systems for measuring and quality control in the industry Betonelement a/s one of Denmark's leading manufacturers of precast concrete elements with eight production centres in Denmark Other participants include NCC Råstoffer, Dragsholm Beton ApS, Eminent a/s, Elkem Materials (Norway) and the Danish Road Directorate ■ RESEARCH Informatics and Mathematical Modelling (IMM) at the Technical University of Denmark, a leading research centre for advanced mathematical modelling and advanced IT systems. Also associated with the project are the Department of Civil Engineering at the Technical University of Denmark, the Ecole Polytechnique Fédérale de Lausanne in Switzerland, the Eidgenössische Materialprüfungs- und Forschungsanstalt in Switzerland and The Benchmark Centre for the Danish Construction Sector.	SCC-CONSORTIUM ■ A TECHNOLOGICAL BREAKTHROUGH set to improve productivity and the working environment in the construction industry SELF-COMPACTING CONCRETE
SCC-CONSORTIUM	WWW.SCC-KONSORTIET.DK	

SCC-Consortium

THE CONCRETE

SCC, OR SELF-COMPACTING CONCRETE, IS THE CONCRETE OF THE FUTURE - A MATERIAL THAT WILL BRING GREAT ADVANTAGES TO THE CONSTRUCTION INDUSTRY AND SOCIETY AS A WHOLE

SCC is not only capable of increasing productivity in the building industry, its use can also dramatically improve the working environment. What's more, SCC provides architects with new possibilities for the design of beautiful concrete structures. The resulting structures will be of a better quality and more durable than those made using traditional concrete.

■ SCOPE

The SCC Consortium brings together research, development and innovation. Its aim is to improve the working environment in the building industry and to enhance productivity by increasing the use of SCC. SCC differs from traditional concrete in a number of ways, and new expertise is therefore required to exploit the huge potential offered by this material. The SCC Consortium will generate knowledge about SCC and the construction of concrete structures with SCC.

The primary aim of the SCC Consortium is to make SCC the most used type of concrete in Denmark before 2008. In addition, the Consortium is to give the Danish concrete industry a technology jump, making it a world leader in the design and construction of concrete structures with SCC.

OF THE FUTURE

■ STRONG COLLABORATION

The SCC Consortium brings together large and small companies, as well as knowledge centres and leading European research institutions. Close collaboration between suppliers, contractors, building owners and researchers is one of the main strengths of the SCC Consortium, which draws on frontline research as well as practical knowledge from the building trade.

■ EFFORTS

The Consortium's efforts focus primarily on the three areas where SCC offers the greatest potential, namely floors, prefabricated elements and civil engineering. More specifically, the Consortium's activities focus on material development, the construction of concrete structures with SCC and the production of SCC. These activities are carried out under a number of sub-projects which focus on the examination of polymers at the nano-level, the correlation between constituent materials and concrete properties, determination of concrete properties, specification of requirements, the efficient production of SCC using on-line monitoring, and placing SCC.

■ UNIQUE DOCUMENTATION

The SCC Consortium intends to be the first to scientifically document the use of SCC in terms of productivity and the working environment. It will do so with assistance from The Benchmark Centre for the Danish Construction Sector and The Working Environment Centre for Construction.



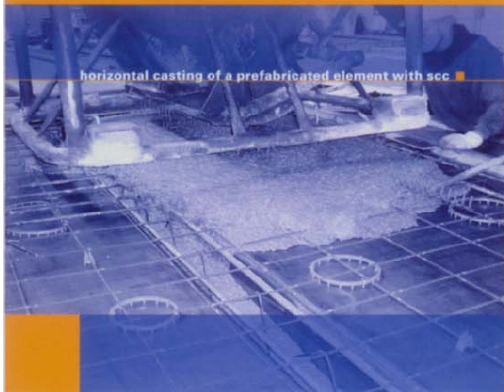
■ in situ casting with SCC

The Benchmark Centre for the Danish Construction Sector will document productivity by means of the key figures generally used to measure construction productivity. The Working Environment Centre for Construction will document both improvements of the working environment as well as new challenges involving SCC.

■ COMMUNICATION

The results of the project will be disseminated by the SCC Consortium via the construction of a bridge for the Danish Road Directorate. The Consortium's findings will also be published in a number of publications, guidelines and handbooks that convey new knowledge about SCC and the construction of SCC structures to, among others, concrete suppliers, contractors and consultants.

horizontal casting of a prefabricated element with SCC ■



THE SCC-CONSORTIUM

The SCC Consortium is the abbreviated name for The Innovation Consortium for Self-Compacting Concrete - a technology jump for productivity and working environment in the building industry. The members of the SCC Consortium represent every stage of the value chain, from knowledge centres and research institutions, through the suppliers of raw materials and measuring equipment, to manufacturers, contractors and building owners. The SCC Consortium was established in 2003, and activities are due to continue until 2006. The overall budget represents approximately DKK 20 million, of which DKK 7.7 million are being contributed by the Danish Ministry of Science, Technology and Innovation.

■ a prefabricated SCC element



Unique Documentation

- The Benchmark Centre of the Danish Construction Sector
- The Working Environment Centre for Construction

Communication

- Construction of a bridge for the Danish Road Directorate
- Publications
 - “CtO Beton-Teknik, Selvkompakterende Beton – SCC”
Issued January 2005
- Guidelines
- Handbooks
- Webside: www.scc-konsortiet.dk
- Newsletter no. 2 issued January 2005
- Newsletter no. 3 issued August 2005

Newsletter

Nyhedsbrev nr. 2 fra SCC-Konsortiet

Januar 2005

Det er nu godt et år siden, SCC-konsortiet startede. Projektets deltagere har i november været samlet for at diskutere resultaterne af det første års arbejde. Dette nyhedsbrev vil fortælle om resultaterne på tre udvalgte områder.

Model til beskrivelse af SCCs flydeegenskaber

En af de aktiviteter, der er nået langt i løbet af det første år, er projektet vedrørende udvikling af en materialemodel for SCC.

Målet er en praktisk anvendelig model, der kan benyttes til at sammensætte nye recepter (der dog fortsat skal justeres ved prøveblandning). På sigt er det også meningen, at modellen skal kunne indgå i et beslutningsstøttesystem til korrektion af betonblandinger, mens de stadigvæk er i blanderen.

Det synes indlysende, at modellen skal være praktisk anvendelig, fx på en betonfabrik, men det betyder, at modellen er langt mere end blot en teoretisk formel. Modellen skal være et samspil mellem den matematiske funktion og det, der rent faktisk kan måles på betonfabrikken, samt den måde, modellen skal køres ind på fabrikken (kalibrering).

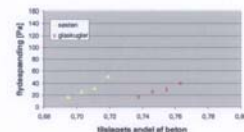


En model er mere end blot en matematisk formel, den er et samspil mellem forskellige faktorer.

Den konkrete model bygger på oplysninger om tilslagslets kornkurve og pakning, tilslagspartiklernes form og pastafasens flydeegenskaber.

Status er, at modellen er afprøvet på laboratorieblandinger og ser ud til at virke fornuftigt. Der mangler endnu at falde enkelte

brikker på plads, herunder en målemetode, der beskriver tilslagspartiklernes form. Alt i alt forventes arbejdet afsluttet i starten af 2005.



Sammenhæng mellem tilslags andel af betonen og betonens flydespænding, der er et mål for hvor stiv, betonen er. (De stiplede linier er modellens forudsigelser, mens punkterne repræsenterer målinger.)

Udvikling af procesudstyr til "fremtidens betonfabrik"

Erfaringsmæssigt er SCC væsentligt mere følsom overfor variationer i fx vandindhold end traditionel sætmalsbeton. Derfor stiller SCC også langt større krav til styring af doserings- og blandeprøven.

De fleste betonfabrikker har i dag et watt-meter tilsat blanderen, som benyttes til at styre dosering af spædevand. Watt-meteret beskriver betonens bearbejdelse ved en enkelt værdi. Denne måde er imidlertid lidt for simpel til at beskrive SCCs flydeegenskaber, hvor det bløde spiller ind hvor stiv betonen er, dvs. hvor stor kraft der skal til at få betonen til at flyde, og hvor tyktflydende, betonen er, når den flyder. Med en såkaldt 2-parameter-måler kan begge disse parametre registreres direkte i blanderen.

I efteråret er der installeret en 2-parameter-måler på en af 4Ks fabrikker i hovedstadsområdet. I øjeblikket måles der parallelt med watt-meteret og det er stadigvæk watt-meter-værdien, der styrer doseringen af spædevand på gammeldags facon. Men der opsamlles løbende måledata med det nye udstyr, der skal evalueres i foråret 2005. Det er forventningen, at der med udgangspunkt i erfaringerne med det nye udstyr kan udvikles en mere præcis styringsmekanisme til regulering af SCCs bearbejdelse baseret på 2-parameter-målinger.

Nyhedsbrev nr. 2 fra SCC-Konsortiet

Januar 2005

Fuldkalibrering i DR-byen

En af SCC-konsortiets delmål er at evaluere forskellige udførelsesmetoder og med det erfaringsgrundlag i bagagen at udarbejde vejledende beskrivelser.

For at kunne opfylde dette delmål er det nødvendigt at afprøve forskellige metoder under sammenlignelige forhold. Det har derfor været SCC-konsortiets store held, at én af projektets kernepartner, MT Højgaard, har vundet licitationen på betonarbejdet på DR-byens Segment 3, og at DR-byen som bygherre er positivt stemt for, at der kan udføres forskellige forsøg på byggepladsen.

Fuldkalibrering startede i uge 52, 2004, med støbning af indre kældervægge.



Klar til støbning af de tre første kældervægge med SCC, DR-byen, Segment 3.



Måling af SCCs friskbetonegenskaber med J-ring, DR-byen, Segment 3.

På byggepladsen vil der bl.a. blive:

- målt flydeegenskaber samtidigt med at betonens udstøbelighed observeres
- målt forstryk

- afprøvet forskellige metoder til anbringelse af beton i formen

Efterfølgende vurderes, hvordan bl.a. overfladekvaliteten afhænger af udførelsesmetode, formoliotype m.v.

Selvom der er tale om indendørs vægge, vil en del af de ca. 5 m høje vægge blive støbt med beton til aggressiv miljøklasse, for at kunne undersøge luftporestrukturen og frostbestandigheden af høje SCC-konstruktioner, hvor luftporene i bunden trykkes sammen pga. de store tryk under udstøbningen.

CIO Beton-Teknik om SCC

SCC-konsortiet har udarbejdet en publikation, der samler den viden, vi allerede i dag har om SCC. Publikationen udgives i januar som CIO Beton-Teknik med titlen *Selvkomprimerende beton – SCC*.

Publikationen behandler bl.a. følgende emner:

- Kort introduktion til betonologi og forklaring på, hvordan SCC adskiller sig fra traditionel beton
- De enkelte delmaterials betydning for SCCs flydeegenskaber
- Praktisk vejledning i proportionering af SCC
- Gode råd om produktion, kontrol og udførelse med SCC

Publikationen kan købes ved henvendelse via e-mail til cio@aalborg-portland.dk eller telefonisk, tlf. 99 33 77 54.

Yderligere information

Se: www.scc-konsortiet.dk

eller kontakt:

Lars Gredstedt - MT Højgaard
Formand for styregruppen
Tlf.: 2270 9816
E-mail: lag@mhøjgaard.dk

Mette Glavind - Teknologisk Institut, Beton
Projektleder
Tlf.: 7220 2220
E-mail: mette.glavind@teknologisk.dk

Webseite: www.scc-konsortiet.dk

SCC-Konsortiet

Et Innovationskonsortium for selvkompakterende beton

[Info](#) [Top 10](#) [Netgroup](#) [In English](#) [Udskriv](#) [Log ind](#) [Søg](#)

Du er her: [SCC-konsortiet](#)

Forside

SCC-Konsortiets kernepartnere

Billede af SCC-Konsortiets medlemmer

[Formidling](#)

[Kontakt](#)

[Nyhedsbreve](#)

SCC-konsortiet

[SCC-Konsortiet](#) | [Baggrund](#) | [Mål](#) | [Fagligt indhold](#) | [Innovationskonsortier](#) | [Parter](#)

Baggrunden for dannelsen af SCC-Konsortiet er, at dansk byggebranche, herunder også betonbranchen, står overfor store udfordringer. Produktivitet, arbejdsmiljø, kvalitet og æstetik er nøglebegreber for at imødekomme fremtidens stadig skærpede krav i den internationale konkurrence. Det er blandt grundene til, at selvkompakterende beton, i daglig tale SCC (fra engelsk: **S**elf **C**ompacting **C**oncrete), er udnævnt som fremtidens betontype.

Beton er verdens vigtigste konstruktionsmateriale. I Danmark produceres årligt ca. 8 mio. tons beton, færdigblandet og til elementer, svarende til 1,5 tons per indbygger. Anvendelse af SCC giver mulighed for markant at forbedre produktivitet, arbejdsmiljø og kvalitet samtidig med, at der åbnes op for konstruktioner med arkitektonisk mere avanceret design.

På trods af, at SCC i dag finder stigende anvendelse i Danmark, er der mange uløste problemer, og i flere lande er anvendelsen af SCC stagneret. Det er derfor nødvendigt at tilføre betonbranchen det teknologiløft, der skal sikre, at SCC kan leve op til forventningerne om fremtidens betontype.

[Næste side »](#)

Dokumentinfo
Dokument ID: 11402,5
Dokumenttype: Forside

Sidst godkendt: 1. november 2004
Sidst revideret: 23. oktober 2003



Webseite: www.VoSCC.dk

**VIDEN
OM SCC**

 **TEKNOLOGISK
INSTITUT**

 **Info**  **Top 10**

 **Udskriv**  **Log ind**  **Søg**

Du er her: [Viden om SCC](#)

[Forside](#) ▲

[01. Hvad er SCC?](#)

[02. Flydeegenskaber](#)

[03. Delmaterialer](#)

[04. Sammensætning af SCC](#)

[05. Produktion](#)

[06. Udførelse af in-situ](#)

[07. Udførelse af elementer](#)

[08. Arbejdsmiljø](#)

[09. Produktivitet](#)

[10. Referencer](#)

[11. Om VoSCC.dk](#)

Viden om selvkompakterende beton



Full scale testing in DR-Byen, Copenhagen

- MT Højgaard won the contract for the concrete works at Segment 3 of the DR-Byen
- DR-Byen as building owner is positively disposed to carry out different tests at the construction site
- The full scale testing began at the end of 2004
- 5 plan inner walls and a core in the cellar has been cast with SCC

Full scale testing in DR-Byen, Copenhagen



Ready for casting the three first walls of the basement in DR-Byen, Segment 3.

SCC used on Fields, Copenhagen



SCC used on Spinderiet, Valby



Further information

- Lars Gredsted – MT Højgaard
Chairman of the Steering Committee
Phone: 22709816
lag@mthojgaard.dk
- Mette Glavind – Teknologisk Institut, Beton
Projectmanager
Phone: 72202220
mette.glavind@teknologisk.dk



MTHøjgaard

Guidelines / Quality Control

Guidelines and Quality Control

Chairman: Kai Westphal

- First SCC in Japan around 1988
- First SCC in Europe around
- 1999 first International SCC Symposium
- 2001 SCC Symposium Tokyo
- 2003 SCC Symposium Reykjavik
- 2005 SCC Symposium Chicago

- Development all over the world
- Conventional test methods not suitable
- New test methods
- Developement of guidelines
- Standards need modifications

- Comparison of Guidelines for SCC
By Kai Westphal
- How is SCC handled in EN Standards
By Steinar Helland

Nordic SCC-Net Workshop

19.06.06 Copenhagen

Comparison of Guidelines for
SCC

Kai Westphal, Dipl.-Ing.

Mest ehf

Iceland

Guidelines

- EFNARC “The European Guidelines for SCC”
May 2005
- Norsk Betonforening “Guidelines for production and use of self-compacting concrete” 2002
- Svenska Betonföreningen “Self-compacting concrete Recommendations for use” 2002
- DAfStb-Richtlinie “Selbstverdichtender Beton”
Dec 2004

EFNARC

Content

- Definitions
- Engineering Properties
- Specifications of self-compacting-concrete
- Requirements of constituent materials
- Mix composition
- Producing ready mixed SCC
- Site requirements
- Placing and finishing on site
- Precast concrete products
- Appearance and surface finish
- Checklist
- Test methods

Norway

Content

- Background / Why is self-compacting concrete different
(matrix models and properties, workability)
- Selection of constituents and proportioning
- Mixing of concrete, operation of mixing plant
(control of water content, mixing equipment, qualitycontrol)
- Transport
(general, after dosage of admixtures, stop in casting operations)
- Treatment and casting
(testing at site, casting method and equipment, formwork)
- Guidance notes, finishing)
- Hardening concrete
(setting, heat development, cracking)
- Curing
- Test methods
- Specifications

Sweden

Content

- Terminology of SCC, constituents, rheological terms and test methods
- Material technology in fresh and hardened stage
- Design aspects and applications
- Recommendations for choice and handling of constituent materials
- Recommendations for production, transport and deliverance
- Recommendations for pumping, casting and finishing (testing at site, casting method and equipment)
- Working environmental effects of SCC
- Comments on existing regulations
- Quality assurance
- Research and development needs
- Test methods

Germany

Content

- General, Definition of SCC
- Personnel and equipment of plants and sites
- Constituents
- Concrete
(consistency, content of fines)
- Quality assurance of the constituents and the SCC
(sample taking, subjects of testing, initial testing)
- Quality monitoring on site and of precast elements
- Production of the concrete and Transportation
(dosing, mixing)
- Conveyance, casting and curing
- Formwork
- Shrinkage and creeping

Slump Flow

■ EFNARC

SF1 550 to 650 mm for e.g. un- or slightly reinforced structures

SF2 660 to 750 mm for normal applications

SF3 760 to 850 mm for vertical applications, very congested structures

Norway

600 to 750 mm for columns or walls

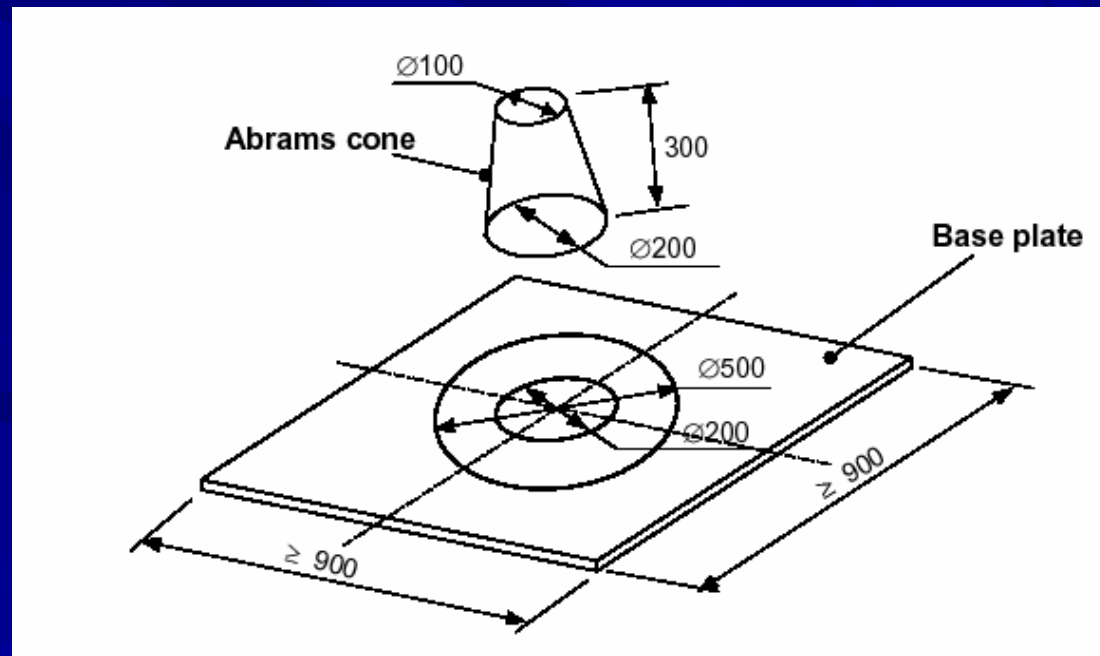
500 to 650 mm for slabs

■ Sweden

no specifications

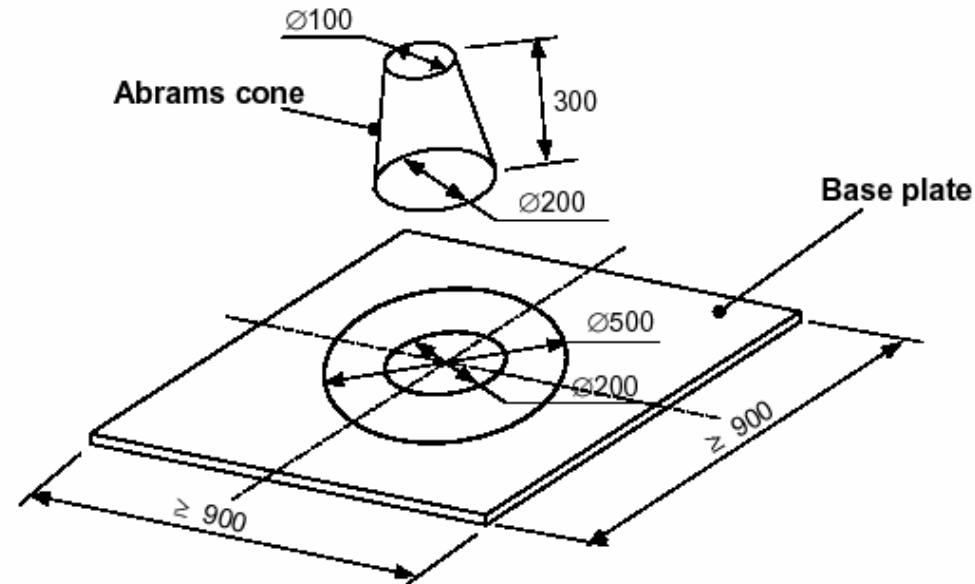
■ Germany

≥700 mm



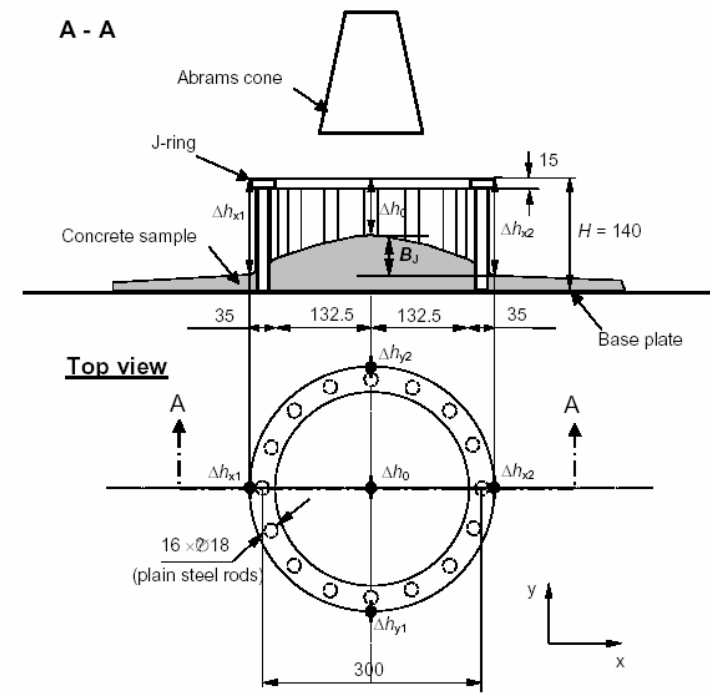
T_{50} Slump Flow

- EFNARC
 $VS1 \leq 2 \text{ sec}$
 $VS2 > 2 \text{ sec}$
- Norway
 $2 \text{ to } 12 \text{ sec for columns or walls}$
 $2 \text{ to } 10 \text{ sec for slabs}$
- Sweden
no specifications
- Germany
no specifications



Slump Flow with J-Ring

- EFNARC
no specifications
- Norway
580 to 730 mm for columns or walls
480 to 630 mm for slabs
- Sweden
no specifications
- Germany
 ≥ 650 mm

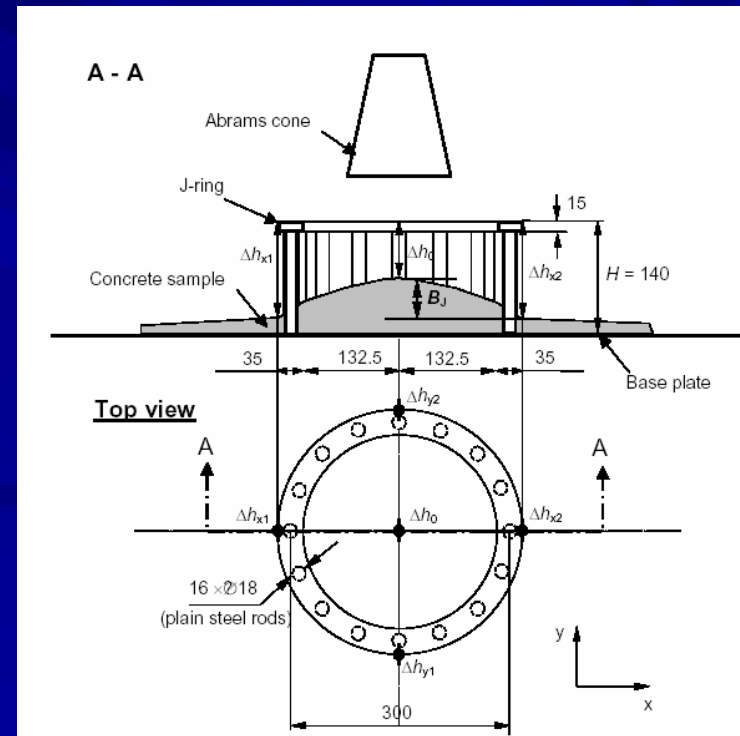


T_{50} Slump Flow with J-Ring

- EFNARC
no specification
- Norway
3 to 15 sec for columns or walls
3 to 12 sec for slabs
- Sweden
no specifications
- Germany
no specifications

J-Ring Height Difference

- EFNARC
no specifications
- Norway
no specifications
- Sweden
no specifications
- Germany
no specifications

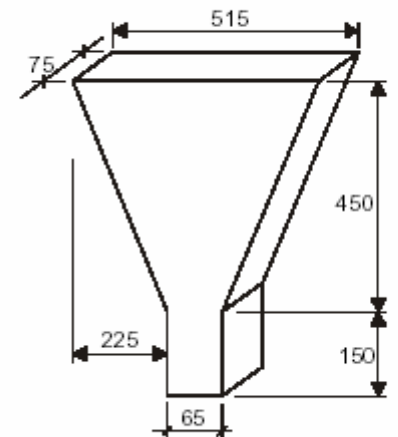


Difference between Slump Flow with and without J-Ring

- EFNARC
no specifications
- Norway
not mentioned
- Sweden
not mentioned
- Germany
 $\leq 50 \text{ mm}$

V-Funnel Test

- EFNARC
 $VF1 \leq 8 \text{ sec}$
 $VF2 \text{ 9 to 25 sec}$
- Norway
not mentioned
- Sweden
no specifications
- Germany
not mentioned



L-Box Test

- EFNARC

PA1 $h_2/h_1 = 0,8$ to 1 with 2 rebars

PA2 $h_2/h_1 = 0,8$ to 1 with 3 rebars

- Norway

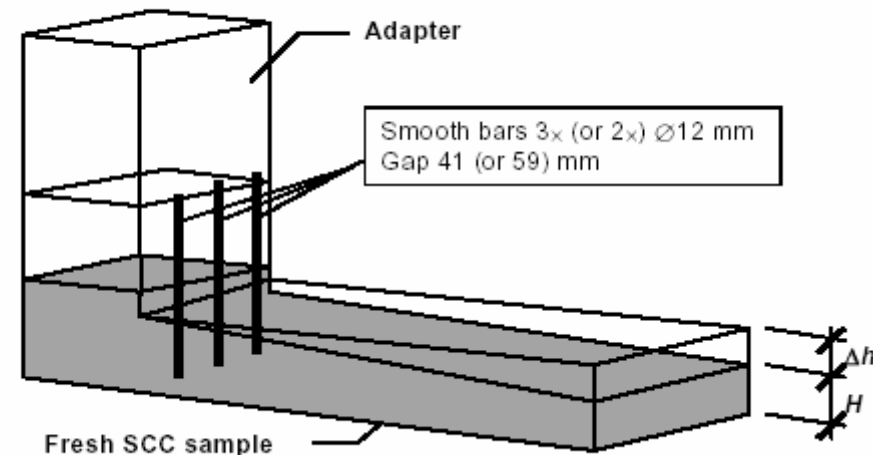
depending on the structure

- Sweden

(0,6) 0,8 to 0,85

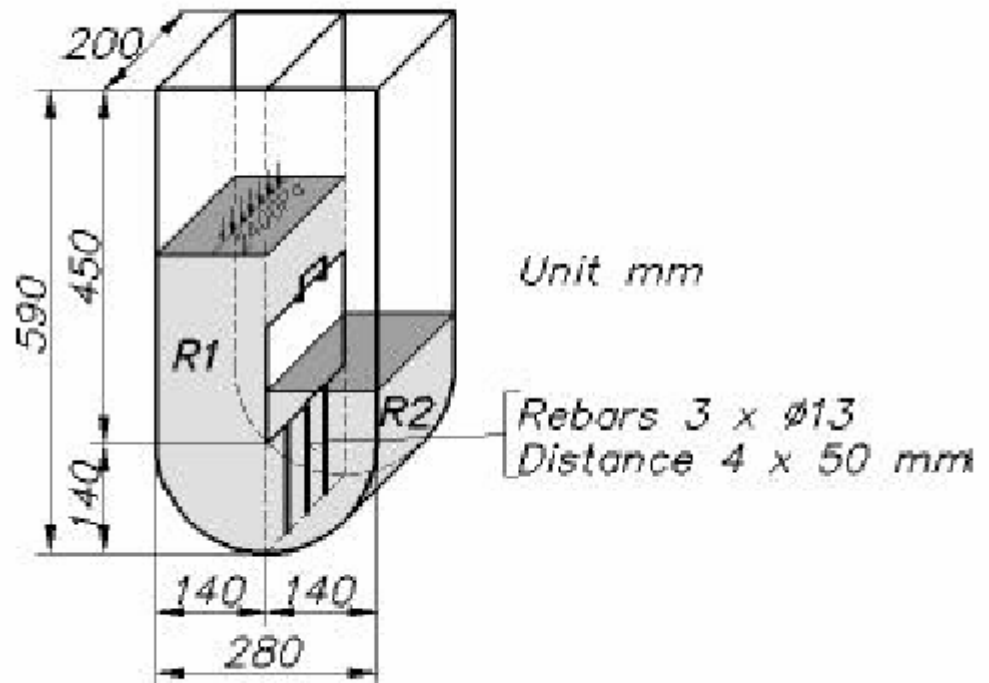
- Germany

not mentioned



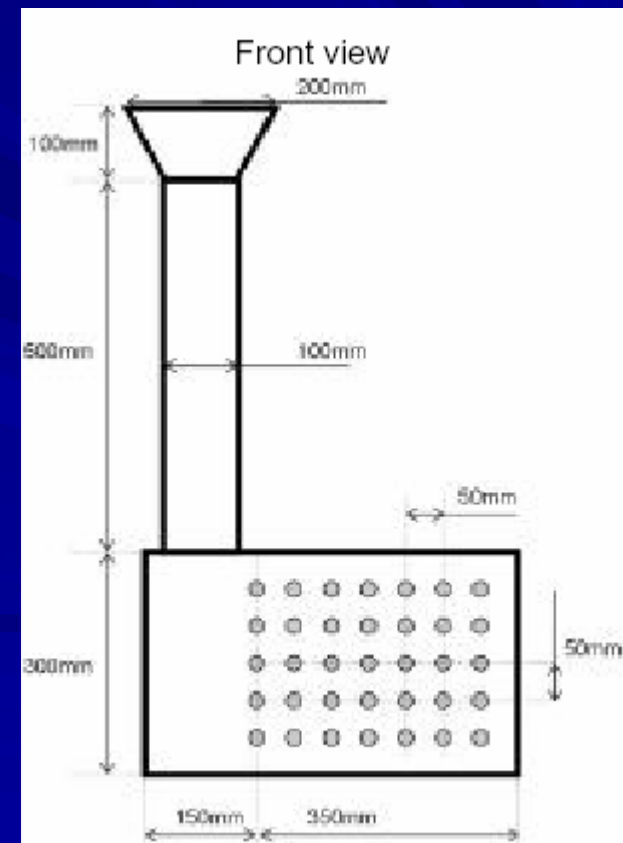
U-Box Test

- EFNARC
no specifications
- Norway
not mentioned
- Sweden
not mentioned
- Germany
not mentioned



Kajima-Box Test

- EFNARC
no specifications
- Norway
not mentioned
- Sweden
not mentioned
- Germany
not mentioned



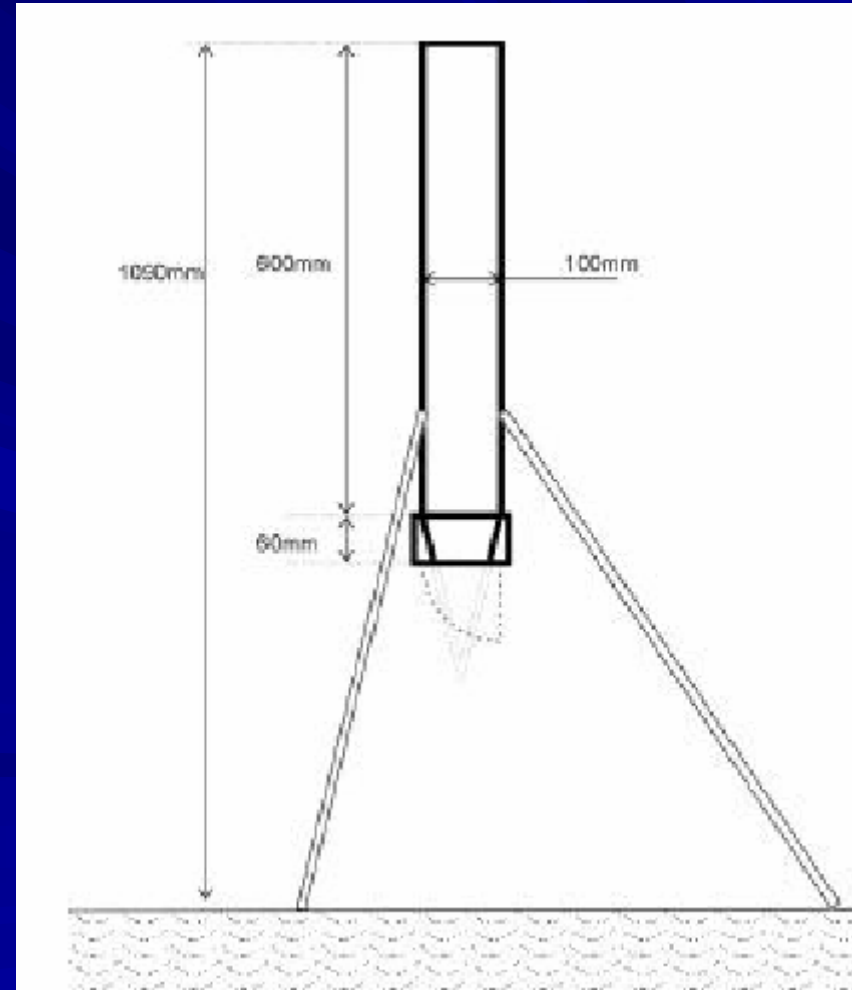
GTM-Stability Test (Sieve Segregation Test)

- EFNARC
 $SR1 \leq 20 \%$
 $SR2 \leq 15 \%$
- Norway
not mentioned
- Sweden
no specifications
- Germany
not mentioned



Orimet Test

- EFNARC
no specifications
- Norway
not mentioned
- Sweden
not mentioned
- Germany
not mentioned



Grooving Test

- EFNARC
not mentioned
- Norway
not mentioned
- Sweden
< 10 sec, otherwise countermeasures
- Germany
not mentioned

Sedimentation Behaviour Test

- EFNARC
no specifications
- Norway
not mentioned
- Sweden
not mentioned
- Germany
no specifications



		Table 1. Summary of the most common test methods used in the design of concrete structures				
		EN 12601		EN 12607		EN 12604
		EFNARC	Norway	Sweden	Germany	
			column/walls	slabs		
Slumpflow	mm	550 – 850	600-750	500-650	no specification	>700
T _{50cm} slumpflow	Sec	VS1≤2 or VS2>2	2-12	2-10	no specification	no specification
Slumpflow with J-Ring	mm	no specification	580-730	480-630	no specification	>650
T _{50cm} slumpflow with J-Ring	mm	no specification	3-15	3-12	no specification	no specification
J-Ring	mm	no specification	3-15	3-12	no specification	
Slumpflow - Slumpflow with J-Ring	mm	not mentioned	not mentioned	not mentioned	not mentioned	<50
V-funnel	sec	VF1≤8 or VF2 9-25	not mentioned		no specification	not mentioned
L-box	(h ₂ /h ₁)	PA1≤0,8 2 rebars PA2≤0,8 3 rebars	depending on structure		(0,6) 0,8 to 0,85	not mentioned
U-box	(h ₂ -h ₁)	no specifications	not mentioned		not mentioned	not mentioned
Fill-box	%	no specifications	not mentioned		not mentioned	not mentioned
GTM Screen stability test	%	SR1 ≤ 20 % SR2 ≤ 15%	not mentioned		no specification	not mentioned
Orimet	sec	no specifications	not mentioned		not mentioned	not mentioned
Flow Cyl.	I _Q	not mentioned	0.55-0.75		not mentioned	not mentioned
					< 10 sec otherwise counter- measures	
Grooving	sec	not mentioned	not mentioned			not mentioned
Tixometer	Nm	not mentioned	not mentioned		no specification	not mentioned
Sedimentation Behaviour		no specifications	not mentioned	not mentioned	not mentioned	no specification

Content of Fines (≤ 0.125 mm)

- EFNARC

$$380 \text{ kg/m}^3 \leq \text{Fines} \leq 600 \text{ kg/m}^3$$

- Norway

no requirements

- Sweden

no requirements

- Germany

$$450 \text{ kg/m}^3 \leq \text{Fines} \leq 650 \text{ kg/m}^3$$

Water/Powder -Ratio

- EFNARC

w/p ratio by volume 0.85 to 1.10

- Norway

without stabilizer 0.30 to 0.45, otherwise stabilizer is recommended

- Sweden

powder type, powder+stabilizer type and stabilizer type SCC mentioned, higher w/p-ratio's demand finer powder

- Germany

no requirements

Water/Cement -Ratio

- EFNARC

based on requirements in EN 206

- Norway

no requirements

- Sweden

no requirements

- Germany

no requirements

Watercontent

- EFNARC

typically 150 - 210 l/m³

- Norway

no requirements

- Sweden

no requirements

- Germany

no requirements

Maximum Grainsize

- EFNARC

usually 12 - 20 mm

- Norway

≤ 16 mm as a recommendation

- Sweden

≤ 16 mm as a recommendation

- Germany

≤ 16 mm

Personal Evaluation

EFNARC

- Most specific regarding ranges of test results
- No background informations
- Practical help how to produce, transport and place SCC on site and in precast production
- Tips for trouble shooting
- Good discription of the test methods
- Best practical guideline for concrete producers

Personal Evaluation

Norway

- Practise orientated guideline
- Theoretical background and explanation why SCC is different
- Background for mix-design approach, but not very specific
- Test result requirements for field testing
- Different requirement for different structures

Personal Evaluation

Sweden

- Main focus on the use of SCC
- Good explanation of the terminology regarding SCC
- Promotion of SCC / advantages and risks
- Nearly no test result requirements

Personal Evaluation

Germany

- Requirements for field and laboratory testing (fresh and hardened concrete)
- Not usable as a stand alone guideline
- Very theoretical, without background informations
- Stiff with little space for new developments

Conclusions

- SCC must become a standard concrete
- Specifications are necessary
- Defined quality control methods
- Assurance for a high quality concrete for the future

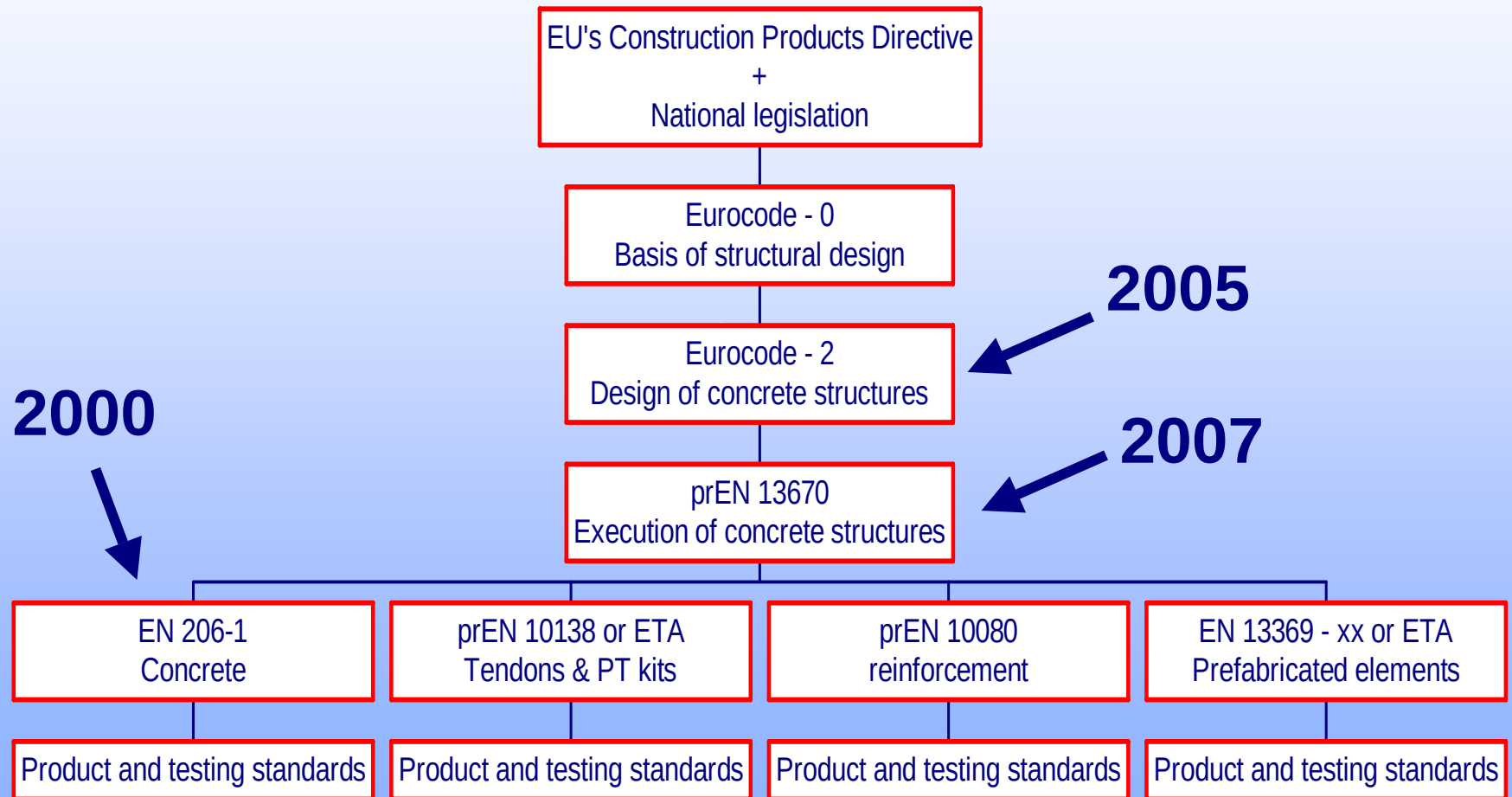
SCC

European standardisation

Nordic Workshop on SCC

Steinar Helland

Present European regulations concerning structural use of concrete



The objectives of including SCC in CEN standards

- 1. Does SCC have properties that are in conformity with the design assumptions in Eurocode 2 ?**
- 2. To regulate the trade between ready-mix producer and contractor**

Present state-of-affairs I

- Default models and mech. properties in EC-2 is based on empirical experience with traditional concrete
- EC-2 and EN 206-1 defines concrete as a mix of water, cement, fine and coarse aggregate etc.
- EN 12620 has later defined "coarse aggregate" as ≥ 4 mm
- Such "concrete" does not support the design assumptions of EC-2 concerning "aggregate interlock", shrinkage, creep, "rotation capacity" etc.

Present state-of-affairs II

- SCC is per today not mentioned once in any CEN standard
- What is SCC ?
- Can it be used within the standards ?
- How to order it from a ready-mix plant ?
- Is it the contractor or the ready-mix producer that guarantee the self compactability ?

Present state-of-affairs III

- CEN TC 250/SC2 (Eurocode-2 / prof. Guiseppe Mancini) has been asked by me (TC 104/SC2) to sort out the data base for the present default models and mech. properties in EC-2
- SCC was on the agenda for TC 104/SC1 (EN 206-1) at its meeting on Cyprus last November.

Present state-of-affairs IV

- CEN TC 104/SC1 initiated the standardisation of 5 test methods for the characterization of the fresh properties of
 - L-box
 - Slumpsread
 - V-funnel test
 - Sieve segregation resistance test
 - J-ring test



Present state-of-affairs V

Resolution 336 (Larnaca 2005-11-02)
CEN/TC 104/SC 1 establishes a new task group 16 "Provisions for SCC" and requests the task group to prepare a report on the different provisions regarding the requirements for SCC (testing, product requirements and the relationship with the execution requirements) in the CEN-member countries within the next 18 months. The report should be drafted in a way, that the relevant parts may be introduced in the future EN 206. Members of the new TG 16 are: L. Meyer (Convenor), FR (Mr Delort will announce), DK (Mr Bager will announce), SE (Mr Sandahl will announce), NL (Mr Cornelissen will announce), UK (Mr Harrison will announce), Mr Biasioli, Mr Marino, Mr Cussigh (on behalf of SC 2).

Tor Arne Hammer is Norwegian expert in the TG

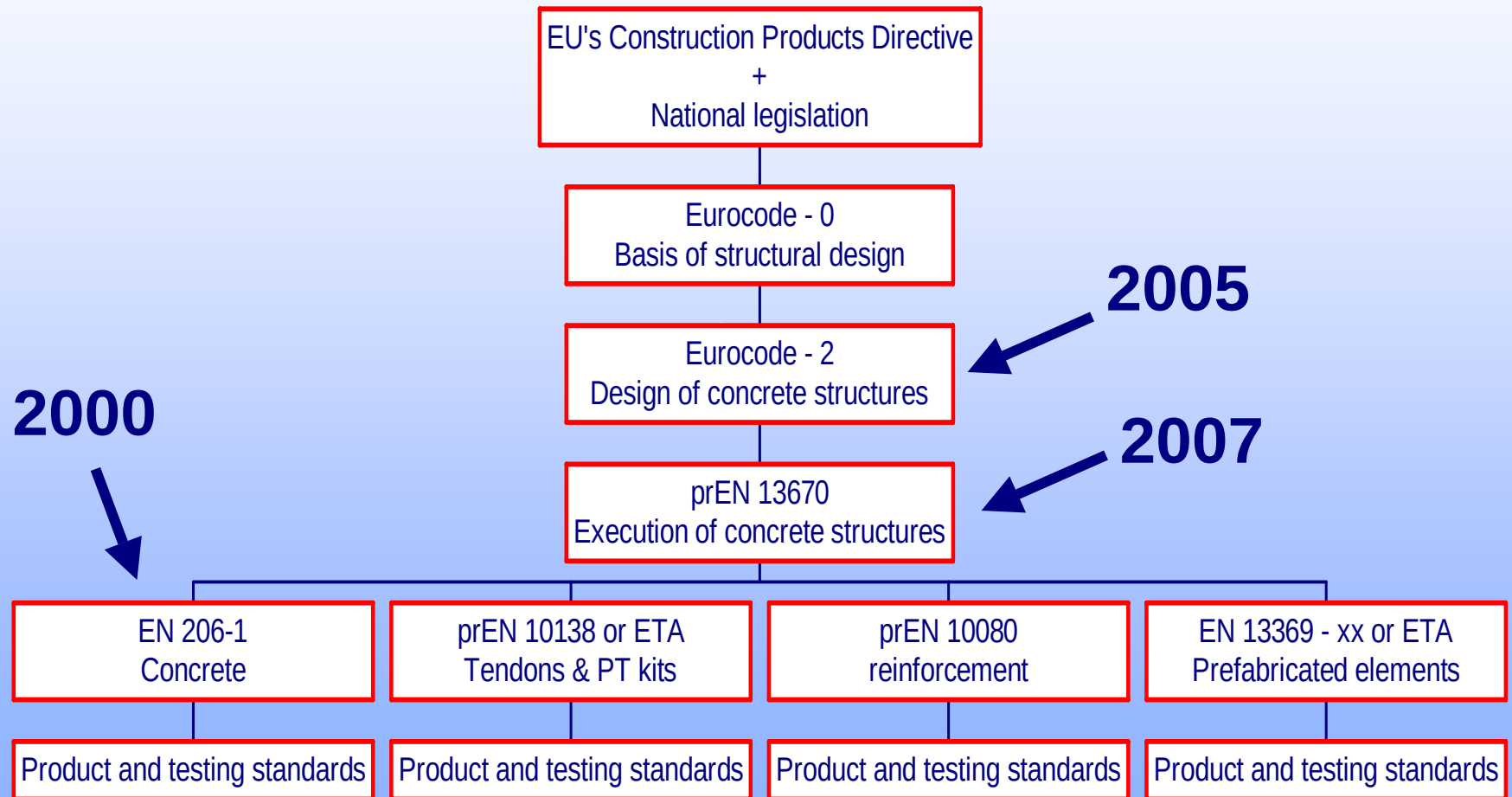
TG 16 will report in Stockholm in June 2007

**Europe is exhausted by the
implementation of EN 206-1 and EC-2**

**None of these will be subject to any
revision in this decade**

**The only main module in the
hierarchy still under production is the
execution standard, prEN 13670**

Present European regulations concerning structural use of concrete



- **prEN 13670 plan to give a requirement to the contractor that the designer has to be contacted if the concrete mix planned to be used is outside some given criteria ($D_{\max}$ and / or paste content)**
- **The EC-2 committee is asked to give us guidance for the criteria**

prEN 13670 § 8.5 Self Compacting Concrete

(1) By the use of concrete described as Self Compacting Concrete (SCC), the needed compaction of the fluid concrete is achieved due to the effect of gravity. Working procedures, for the actual cast, that shall ensure that the required compaction will be obtained shall be established based on the constructors experience and/or pretesting. Additional requirements to those given in EN 206-1 to the fresh concrete properties and its conformity criteria shall be agreed with the producer.

Informative annex to prEN 13670

F.8.4.2 Placing and compaction – Self compacting concrete

(1) SCC mix design should comply with specific requirements in the fresh state depending on the type of application, and especially on:

- confinement conditions related to the concrete element geometry and the quantity, type and location of reinforcement, inserts and recesses;
- placing equipment (pump, truck-mixer, skip);
- placing methods (number of delivery points);
- finishing method.

Those requirements might be expressed and justified in terms of:

- flowability and filling ability;
- viscosity (measure of the speed of flow);
- passing ability, (flow without blocking);
- segregation stability.

Informative annex to prEN 13670

(2) The required consistence retention time depends on the transportation and placing time. This should be determined and specified.

(3) Self-compacting concrete should, as much as possible, be placed in one continuous pour so delivery rates should be matched to placing rate. Maximum allowed period of time between successive concrete layers should be declared and kept under control.

(4) Free-fall of SCC should be limited in order to avoid any adverse effect on concrete quality and homogeneity.

(5) Horizontal flow of SCC should be limited in order to avoid any adverse effect on concrete quality and homogeneity.

Informative annex to prEN 13670

(6) Vibration of SCC should generally be avoided as it is likely to result in significant segregation of the coarse aggregate. A carefully controlled and light vibration can be used if it is demonstrated that there is no adverse effect on concrete quality and homogeneity.

NOTE 1 At the time of publishing the standard, CEN has not completed its work to standardize test methods characterizing the properties of SCC nor additional provisions for its specification in EN 206. Till such CEN-provisions are available, the constructor and the concrete producer might find guidance in national and European guidelines published by other bodies.

NOTE 2 Guidance regarding limitation of free-fall and horizontal flow can be found in published guidelines (e.g. RILEM SCC Technical Committee report).

Conclusion

- **SCC is still controversial in parts of Europe**
- **The challenge is to identify "extreme mix-composition"**
- **The minor challenge is to sort out the communication between ready-mix producer and contractor**

"SCC"



"SCC"





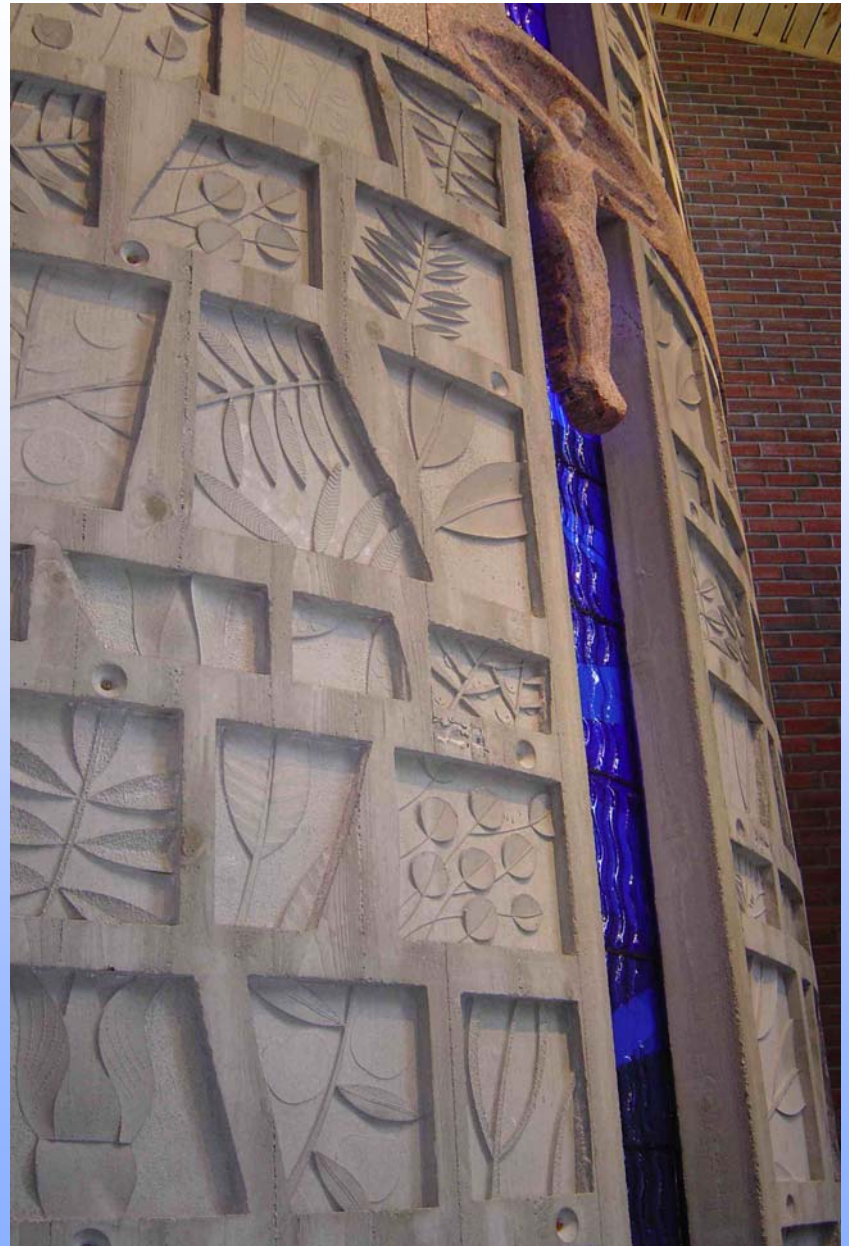
"SCC"

"SCC"



**Example of successfully
use of SCC.**

**Tjennvoll church,
Rogaland - Norway**



Holmenkollen - 100 km/h - 5 meters above the ground



Photo:
Steinar Helland
2005

Prepare yourself before taking new technology into use !!!

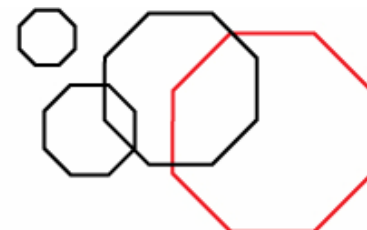
Mix Design

Material Models in SCC Mix Design

Claus Pade, SCC-seminar in Copenhagen, 19 June, 2006



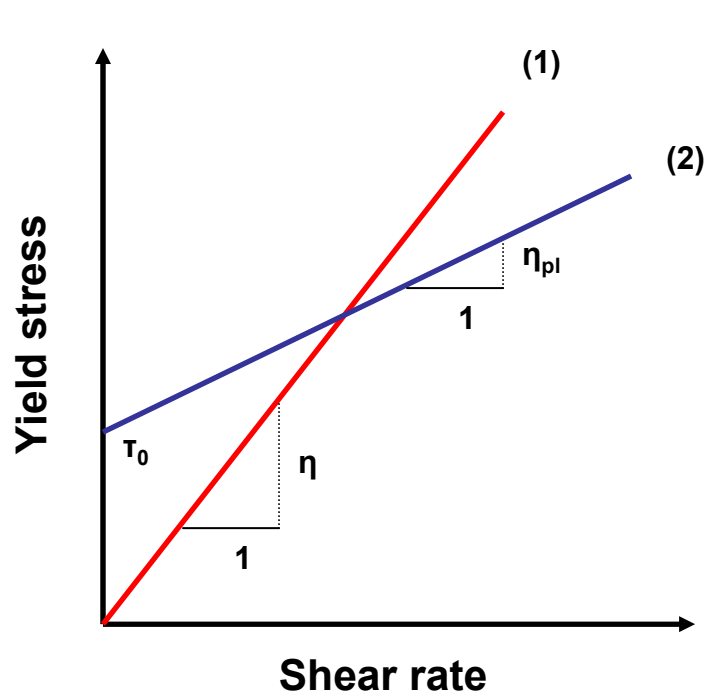
Nytænkning gennem 100 år



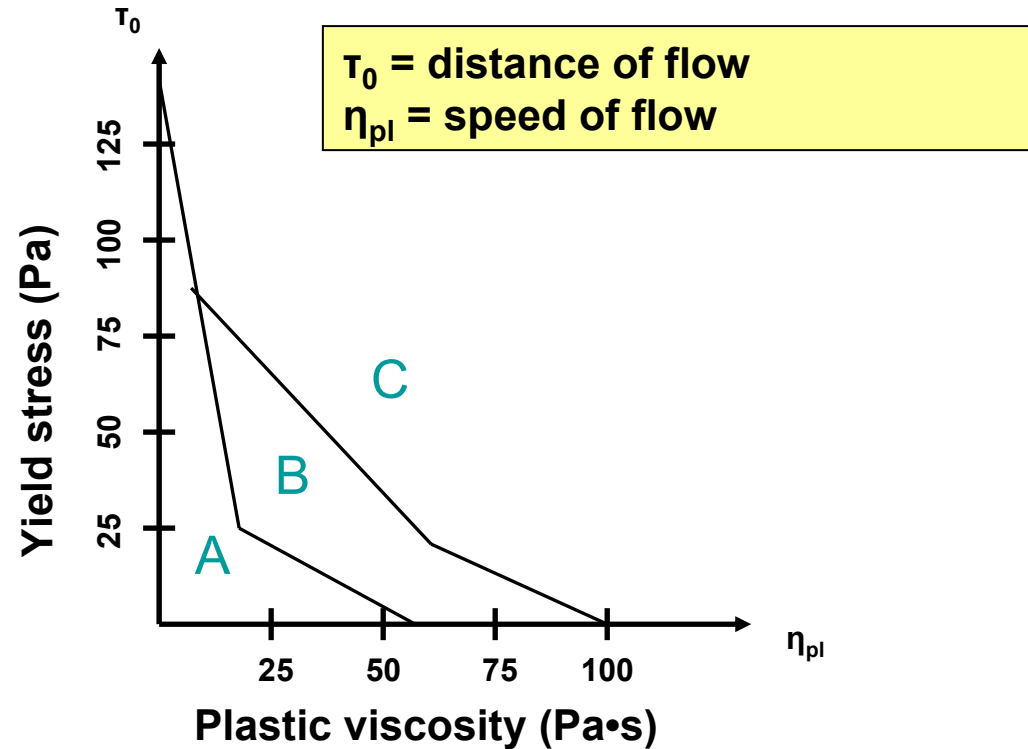
Innovation in 100 years

Role of Model in Mix Design

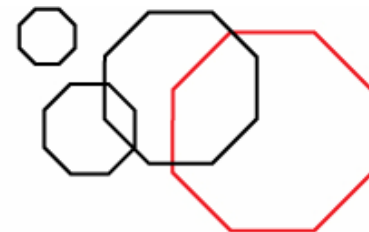
■ Estimate/predict the rheological behavior of concrete



- (1) Newtonian liquid (water)
- (2) Bingham-material (concrete)



- A: Separation
- B: SCC
- C: Not sufficient flow



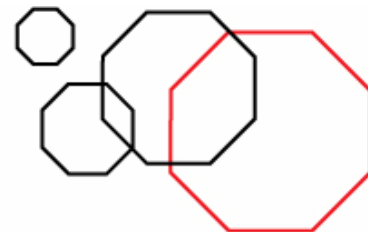
Types of Model

■ Emperic

- Too simplistic
- It works but you don't know why

■ Analytic

- Too complicated
- It works and you know why



Danish SCC-Consortium Model

Originally proposed by Oh et al.:

$$\eta_{concrete} = \eta_{paste} \left(A_{\eta} \cdot \Gamma^{-B_{\eta}} + 1 \right)$$

$$\tau_{0,concrete} = \tau_{0,paste} \left(A_{\tau} \cdot \Gamma^{-B_{\tau}} + 1 \right)$$

$$\Gamma = \frac{1 - \varphi / \varphi^*}{f/k \cdot \varphi}$$

$\eta_{concrete}$, is the plastic viscosity of the concrete

η_{paste} , is the plastic viscosity of the paste

$\tau_{0,concrete}$, is the yield stress of the concrete

$\tau_{0,paste}$, is the yield stress of the paste

A_{η} , A_{τ} , B_{η} , B_{τ} , are constants

Γ , is the relative thickness of excess paste

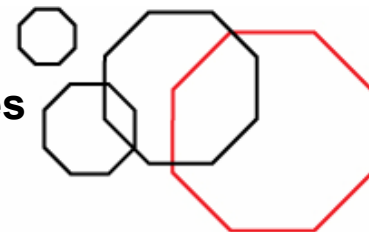
φ , is the volume fraction of the aggregate

φ^* , is the max volume fraction of the aggregate

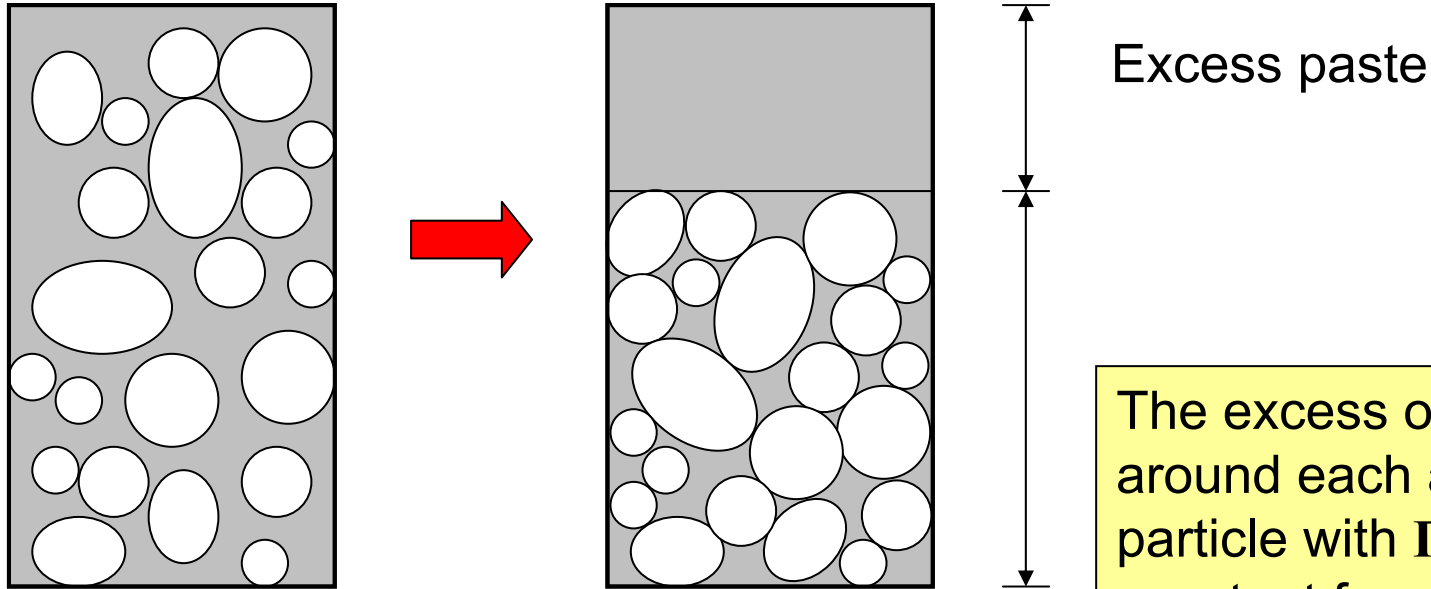
f/k , is a shape factor – related to the ratio between surface and volume of a particle with characteristic dimension 1

f/k (sphere) = 6

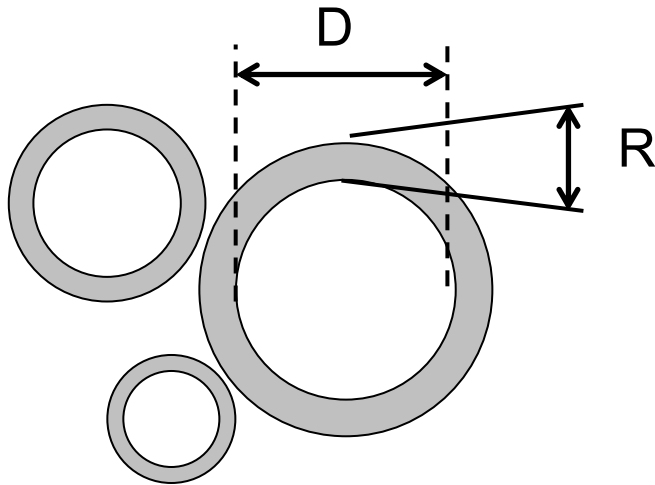
$f/k > 6$ for all other shapes



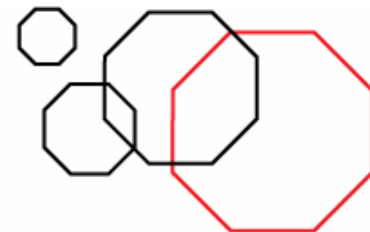
Elements of the Model



The excess of paste is found around each aggregate particle with $\Gamma = R/D$ constant for all aggregate particles



$\Gamma = R/D$ is the same for either particle



Experimental Program

$$\tau_{0,concrete} = \tau_{0,paste} \left(A_{\tau} \cdot \Gamma^{-B_{\tau}} + 1 \right)$$

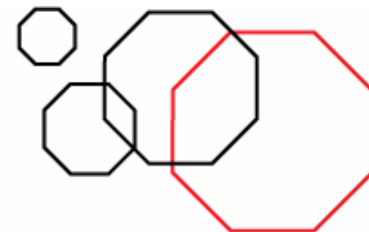
$$\Gamma = \frac{1 - \varphi / \varphi^*}{f / k \cdot \varphi}$$

$\tau_{0,paste}$
 η_{paste}
} EMPA Zürich - Estimated from plate-plate rheological measurements

$\tau_{0,concrete}$
 $\eta_{concrete}$
} DTI - Estimated using 4C Auto Slump Flow equipment

φ^*
 φ / φ^*
 $*$
} DTI - Estimated using the 4C Packing software

f/k
 A
 B
} Fit-parameters in regression analysis



Materials and Composition

Mix 1

0/2	4/8	8/16
Natural pit	Sea dredged	Sea dredged
Max packing	0.808	
w/c	0.35	
SP-konc	0.50	
Excess paste	110,120,130,140 L	

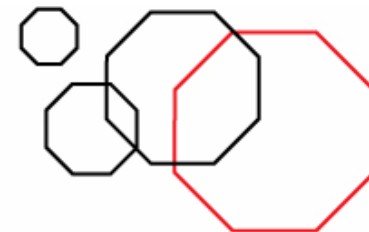
Mix 2

0/2	4/8	8/16
Glass beads	Glass beads	Glass beads
Max packing	0.848	
w/c	0.35	
SP-konc	0.50	
Excess paste	100,110,120,130 L	

Mix 3

0/4	4/8	8/16
Natural pit	Crushed granite	Crushed granite
Max packing	0.804	
w/c	0.35	
SP-konc	0.50	
Excess paste	160,170,180,190 L	

Identical pastes in all three mixtures



4C Packing Diagrams

37,18,45, 0.808

37,18,45, 0.848

8/16

0/4

8/16

0/4

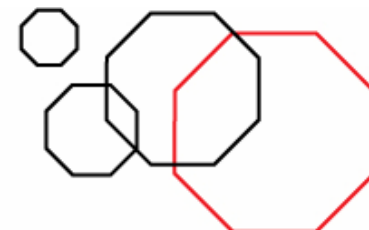
4/8

8/16

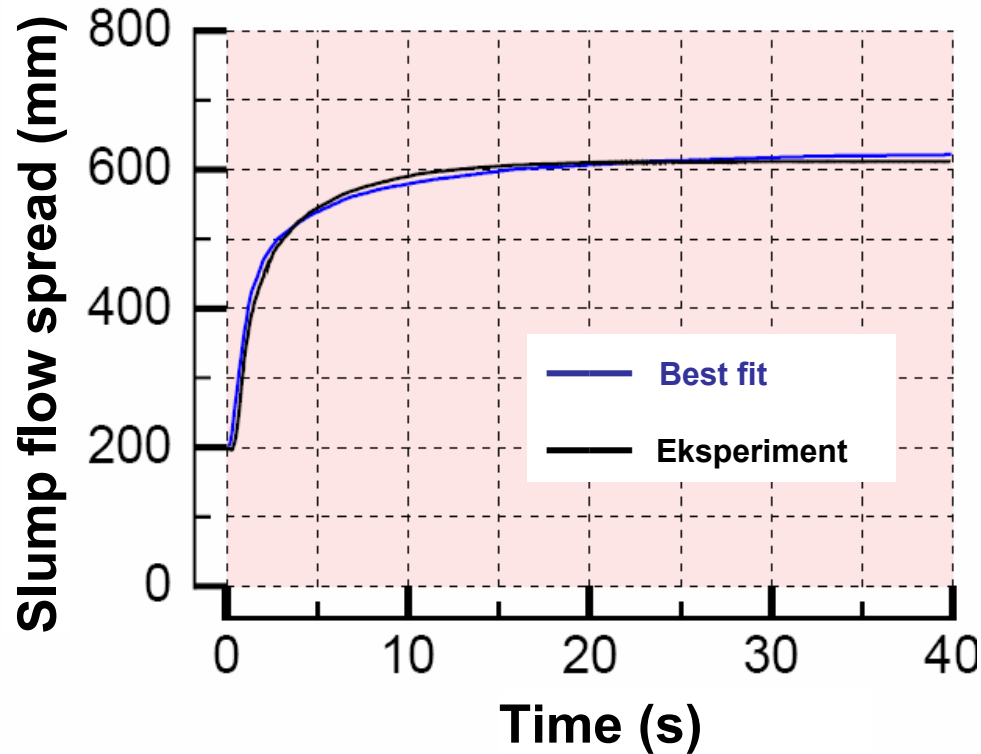
0/4

45,10,45, 0.804

4/8

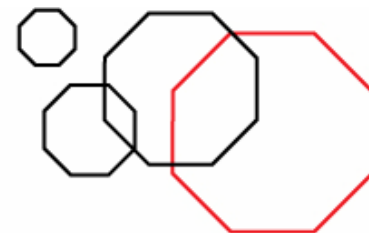


4C Auto Slump Flow



Yield stress = 26 Pa

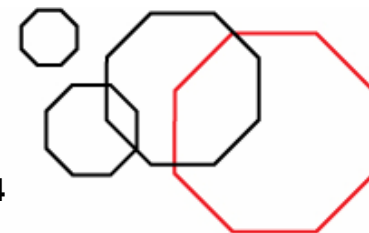
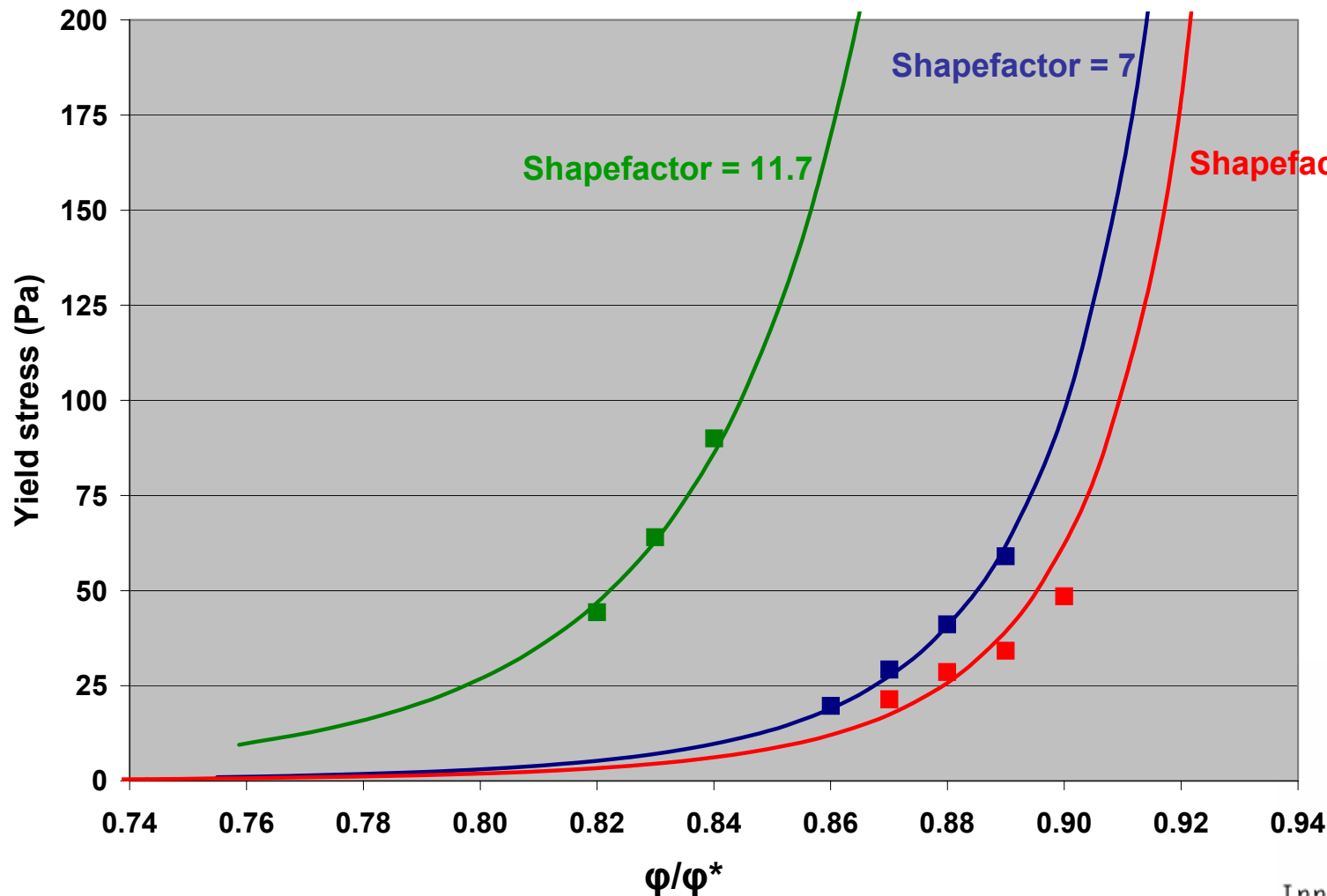
Plastic viscosity = 44 Pa × s



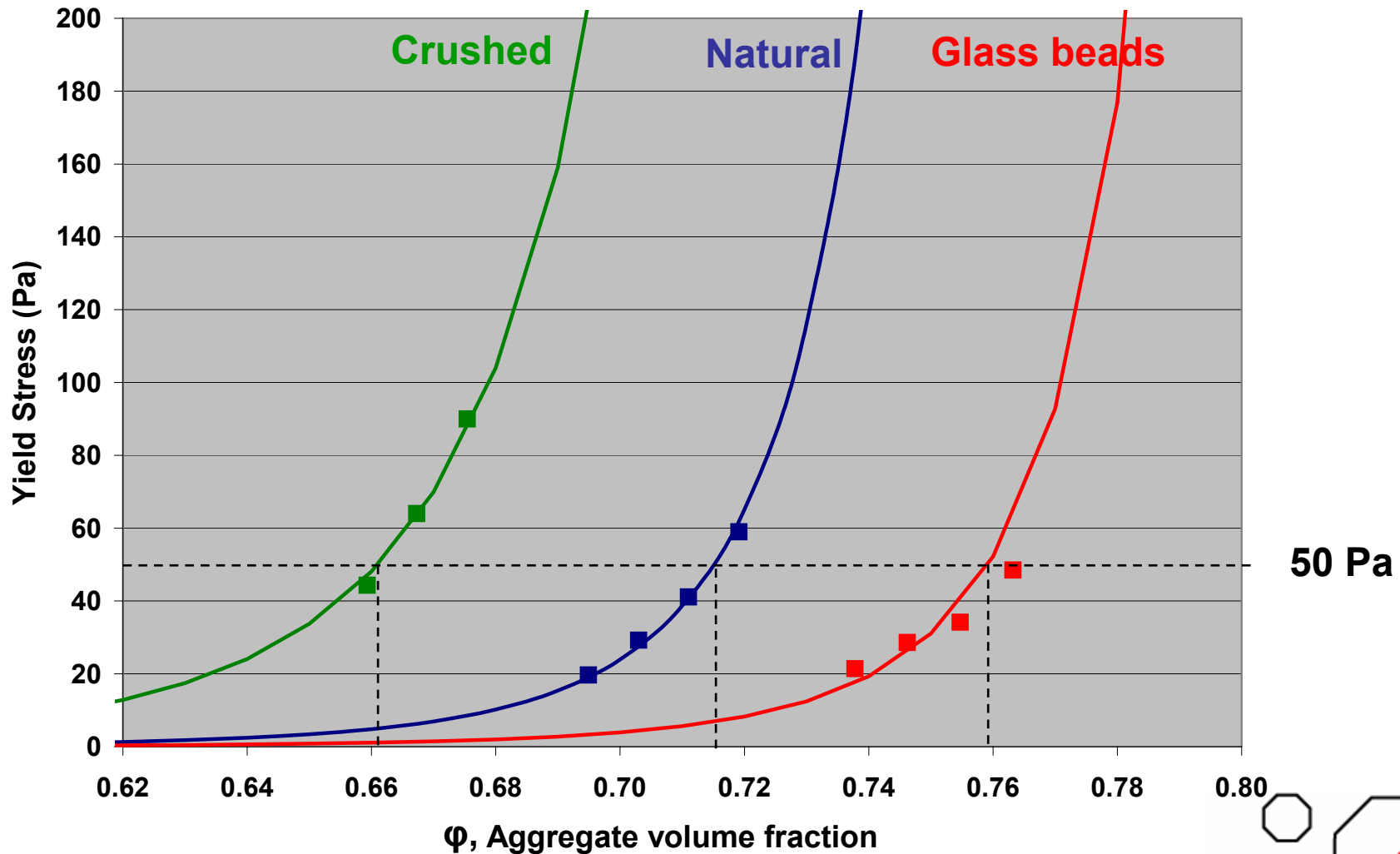
Results – Yield Stress

$$\tau_{0,concrete} = 4.5 \times 10^{-6} \times \Gamma^{-4.3}$$

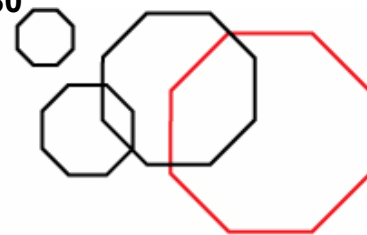
$$\Gamma = \frac{1 - \varphi/\varphi^*}{\text{shapefactor} \cdot \varphi}$$



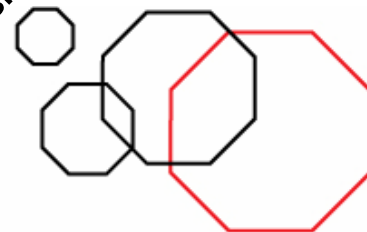
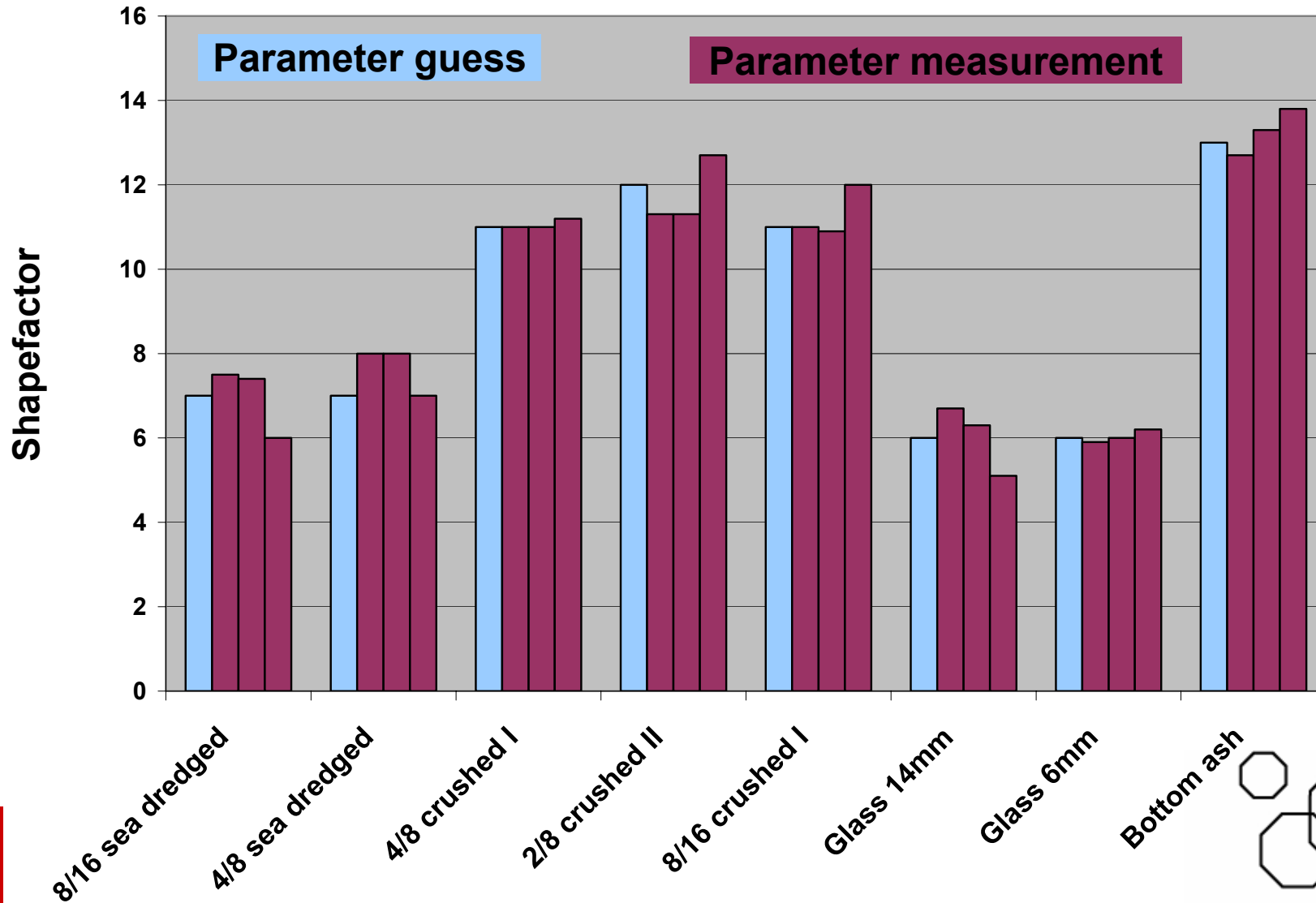
Results – Yield Stress



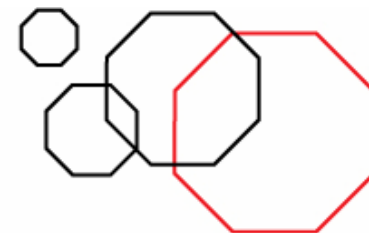
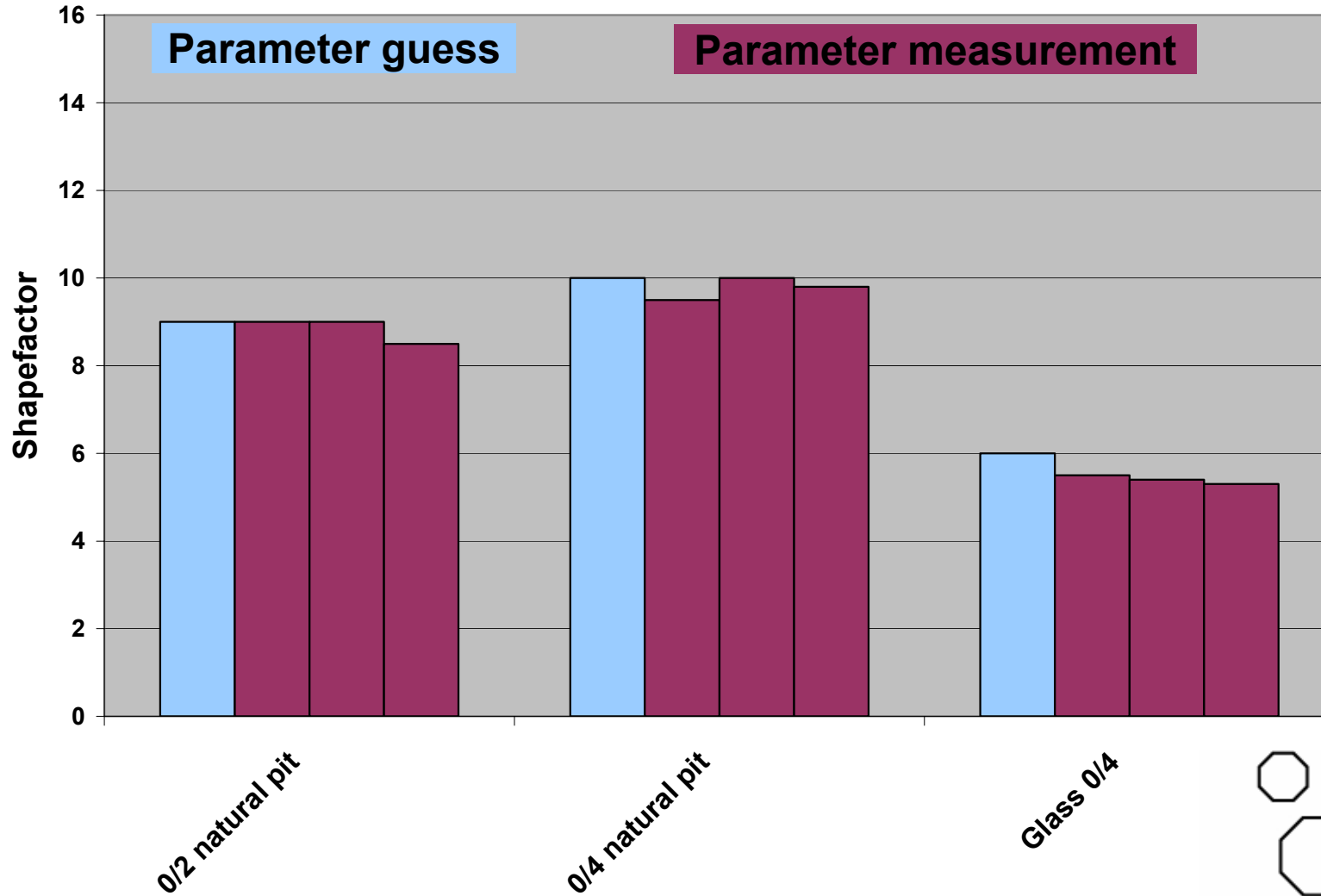
Crushed +100L excess paste
Natural +45L excess paste



Shapefactor – Image Analysis



Shapefactor – Image Analysis



$$\tau_{0,concrete} = \tau_{0,paste} \left(A_{\tau} \cdot \Gamma^{-B_{\tau}} + 1 \right)$$

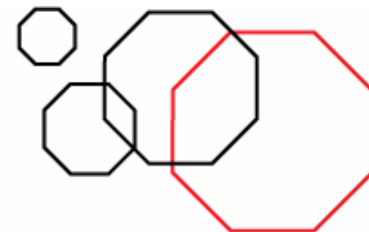
$$\Gamma = \frac{1 - \varphi / \varphi^*}{f / k \cdot \varphi}$$

For practical purpose:

$$\tau_{0,concrete} = A \times \Gamma^B$$

$$\Gamma = \frac{1 - \varphi / \varphi^*}{\text{shapefactor} \cdot \varphi}$$

- Estimate particle packing parameter - φ^* **OK!**
- Select aggregate proportions – φ **OK!**
- Estimate shapefactor ?
- Estimate the constants A and B ?



EFFECT OF FORM PRESSURE ON THE AIR VOID STRUCTURE OF SCC

Mikkel V. Jensen

Department of Civil Engineering,
Technical University of Denmark

Marianne T. Hasholt

Concrete Centre,
Danish Technological Institute

Mette R. Geiker

Department of Civil Engineering,
Technical University of Denmark

Motivation – 1 of 2

The air void structure of a hardened concrete has to satisfy two requirements if the concrete is to be approved in Denmark as **frost resistant**;

- The **total air content** in paste (including air) should be no less than 10 %
- The **spacing factor** must be no more than 0.20 mm



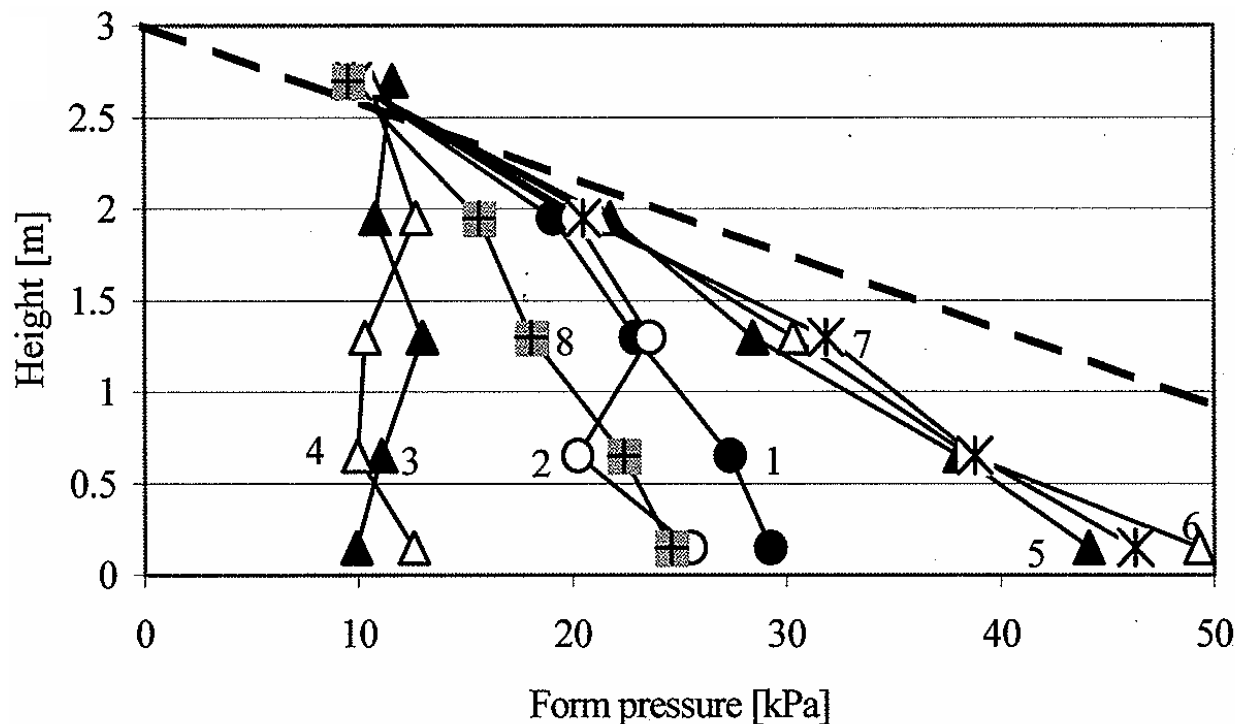
Motivation – 2 of 2

The high workability of self-compacting concrete (SCC)
invites to high casting rates

Motivation – 2 of 2

The high workability of self-compacting concrete (SCC) invites to high casting rates

Casting at high rate may result in **large pressure** at the bottom of the form and **compression of air voids**



[Billberg 2003]

Boyle-Mariottes Law

The pressure related changes of a certain volume of air can be estimated by using Boyle-Mariottes law (constant temperature):

$$p \cdot V = \text{constant}$$

p pressure

V volume

Expected Pressure Related Changes

Total air content, V

$$V_{bottom} = \left(\frac{p_{top}}{p_{bottom}} \right) \cdot V_{top}$$

Radius of air voids, r

$$r_{bottom} = \left(\frac{p_{top}}{p_{bottom}} \right)^{1/3} \cdot r_{top}$$

Expected Pressure Related Changes

Specific surface, α

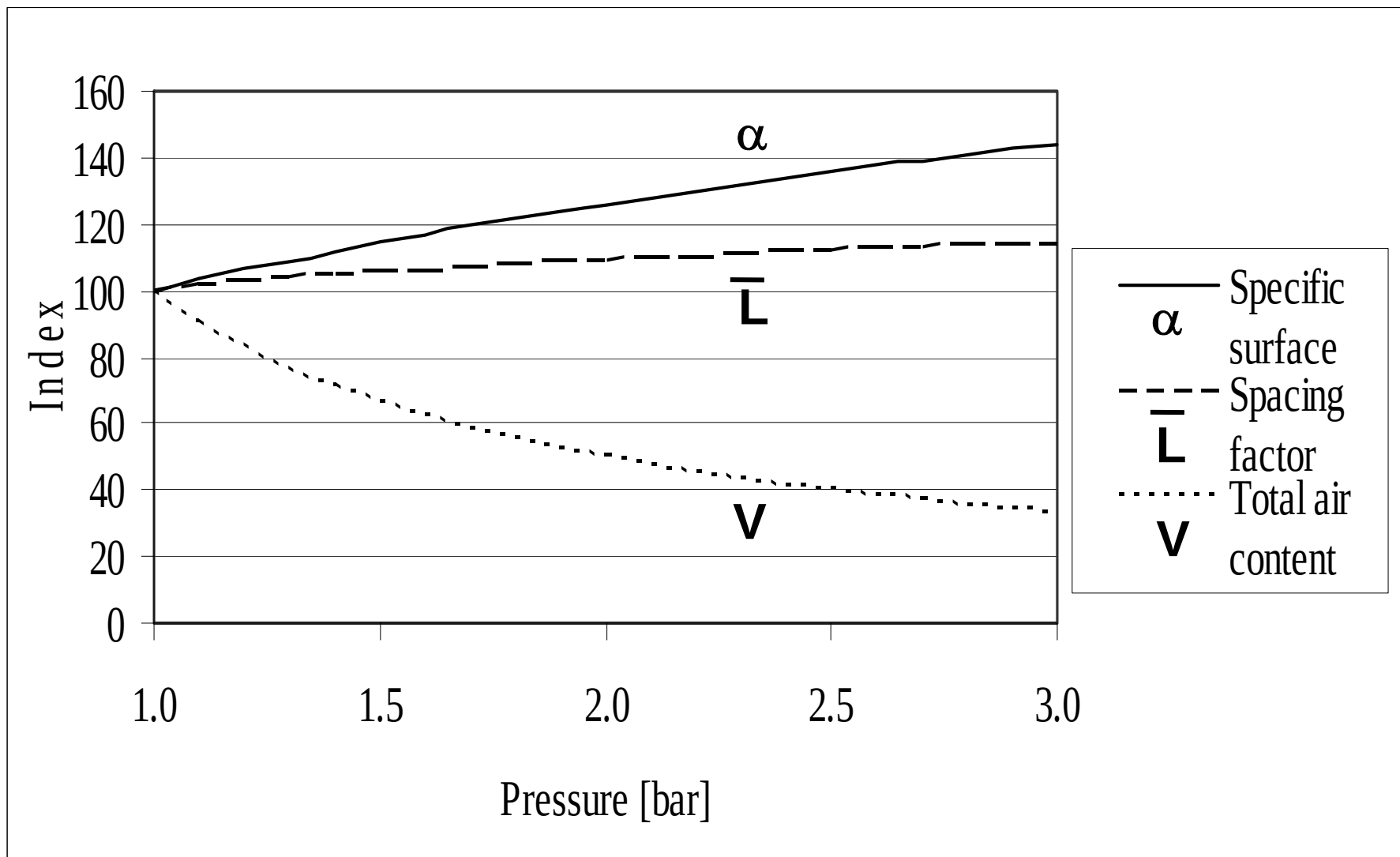
$$\alpha_{bottom} = \left(\frac{p_{top}}{p_{bottom}} \right)^{-\left(\frac{1}{3}\right)} \cdot \alpha_{top}$$

Spacing factor, $\bar{L}$

$$\bar{L} = \frac{3 \cdot (1.4(1 + R)^{\frac{1}{3}} - 1)}{\alpha} \quad R \geq 4,342:$$

R paste / air volume ratio

Expected Pressure Related Changes



Experimental

Laboratory

- 3 concrete batches with approximately 6.5 % air
- 3 concrete batches with approximately 4.5 % air

Full scale wall castings

- Filling from the bottom
- Filling 0.5 m above concrete surface

Experimental (Laboratory) – Concrete Mixes

Constituent material	Unit	“H”	“L”
Cement (CEM I 52.5)	kg/m ³	384	393
Water	kg/m ³	135	138
Sand (0-2 mm)	kg/m ³	661	675
Rounded gravel (4-8 mm)	kg/m ³	316	323
Rounded gravel (8-16 mm)	kg/m ³	800	818
Superplast, Glenium C151	kg/m ³	1.91	1.95
AEA, Conplast 316 AEA1:5	kg/m ³	0.96	0.39
Air content in fresh concrete	%	6.3 ± 0.7	4.7 ± 1.0

Experimental – Testing Laboratory



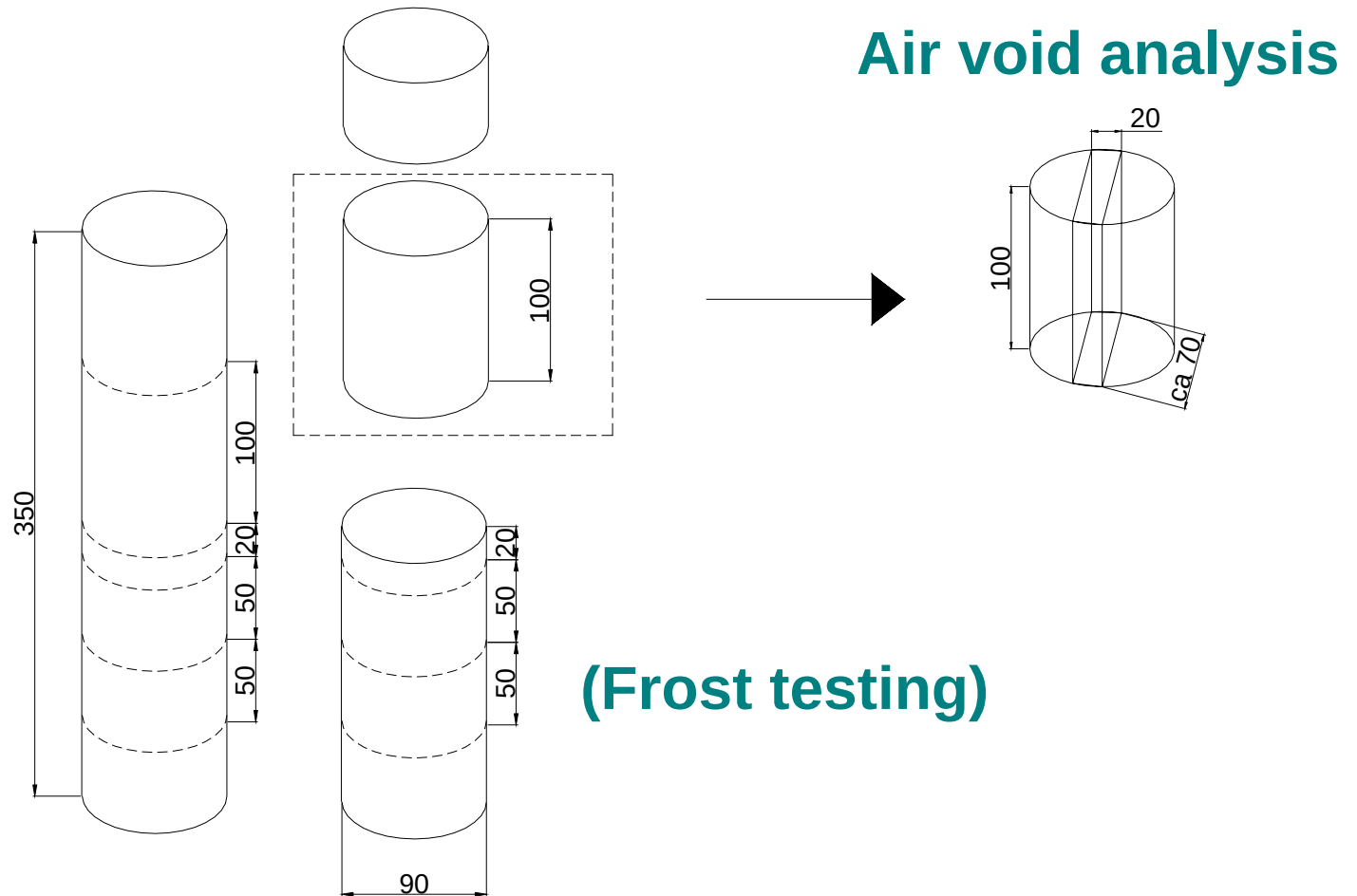
Pressure:

1, 1.5, 2 and 2.5 bar
(0, 2, 4, 6 m concrete)

Duration: 24 hours



Experimental – Testing Laboratory



Air Void Analysis; DS/EN 480-11 (only $\frac{1}{4}$ of required samples size)

Low paste content



High paste content



Experimental – Testing

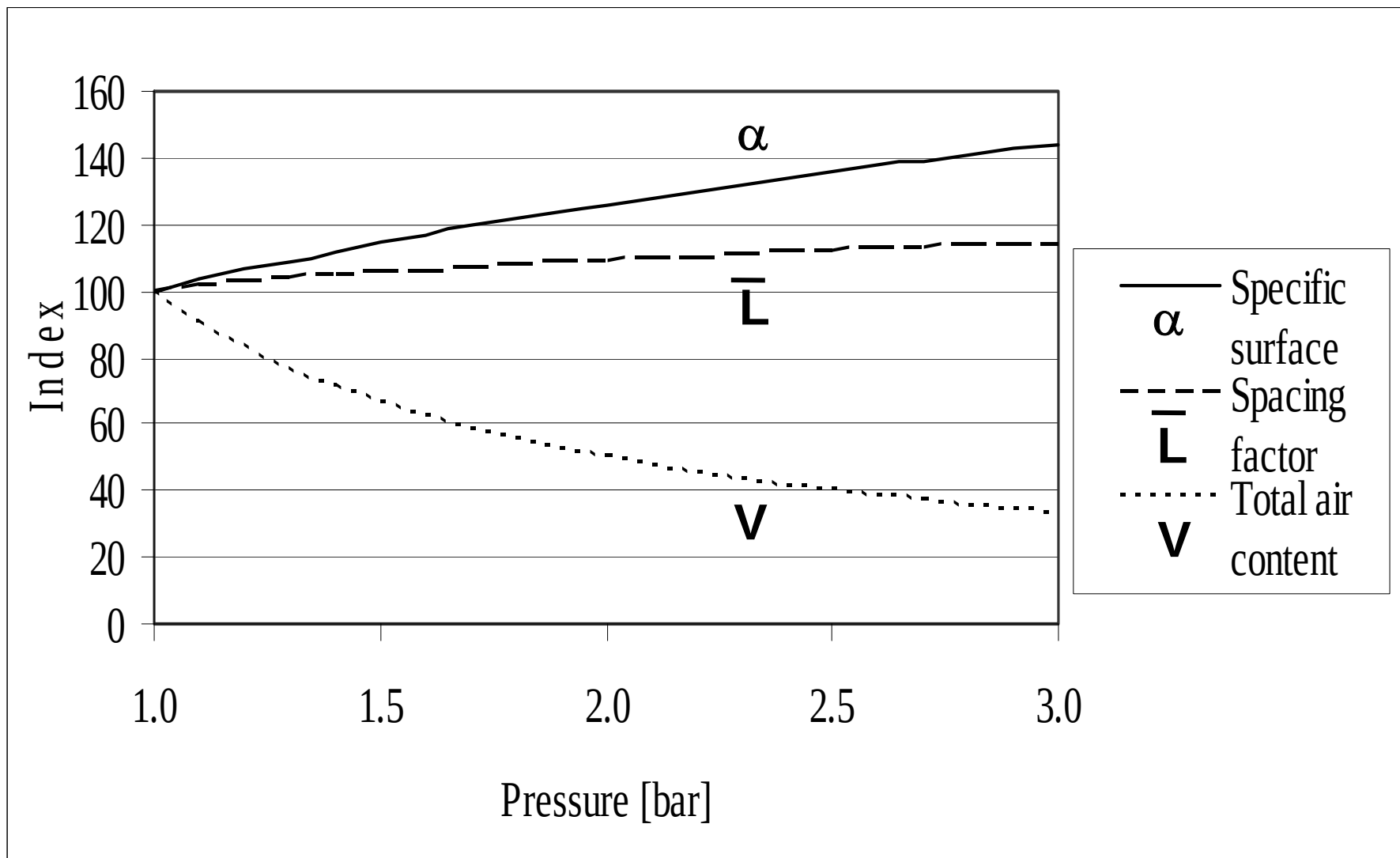
Full Scale



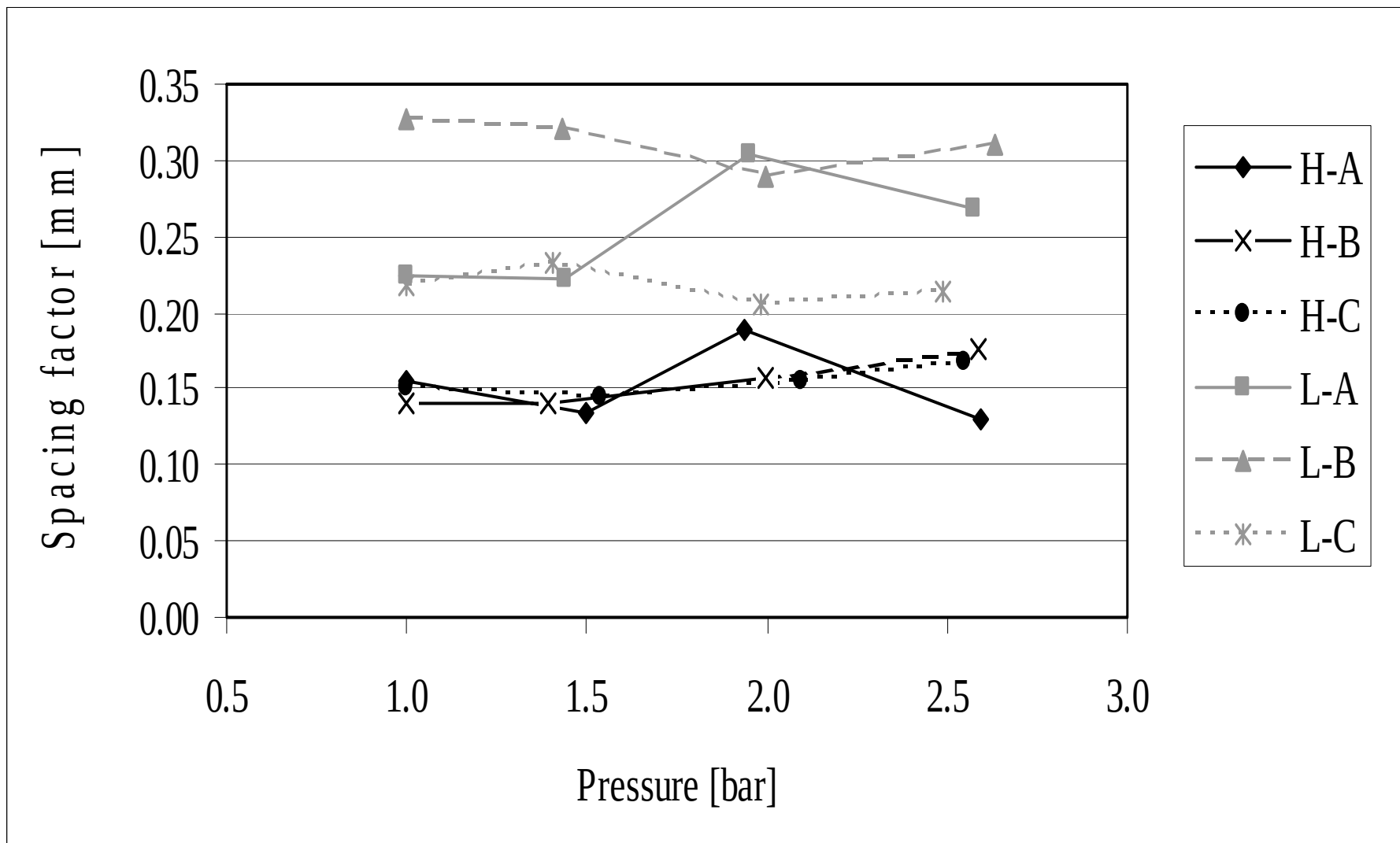
Walls for basement cast December 2004
5-8 % air; $\eta_{pl}=60$ [Pa s]; $\tau_0=20$ [Pa]



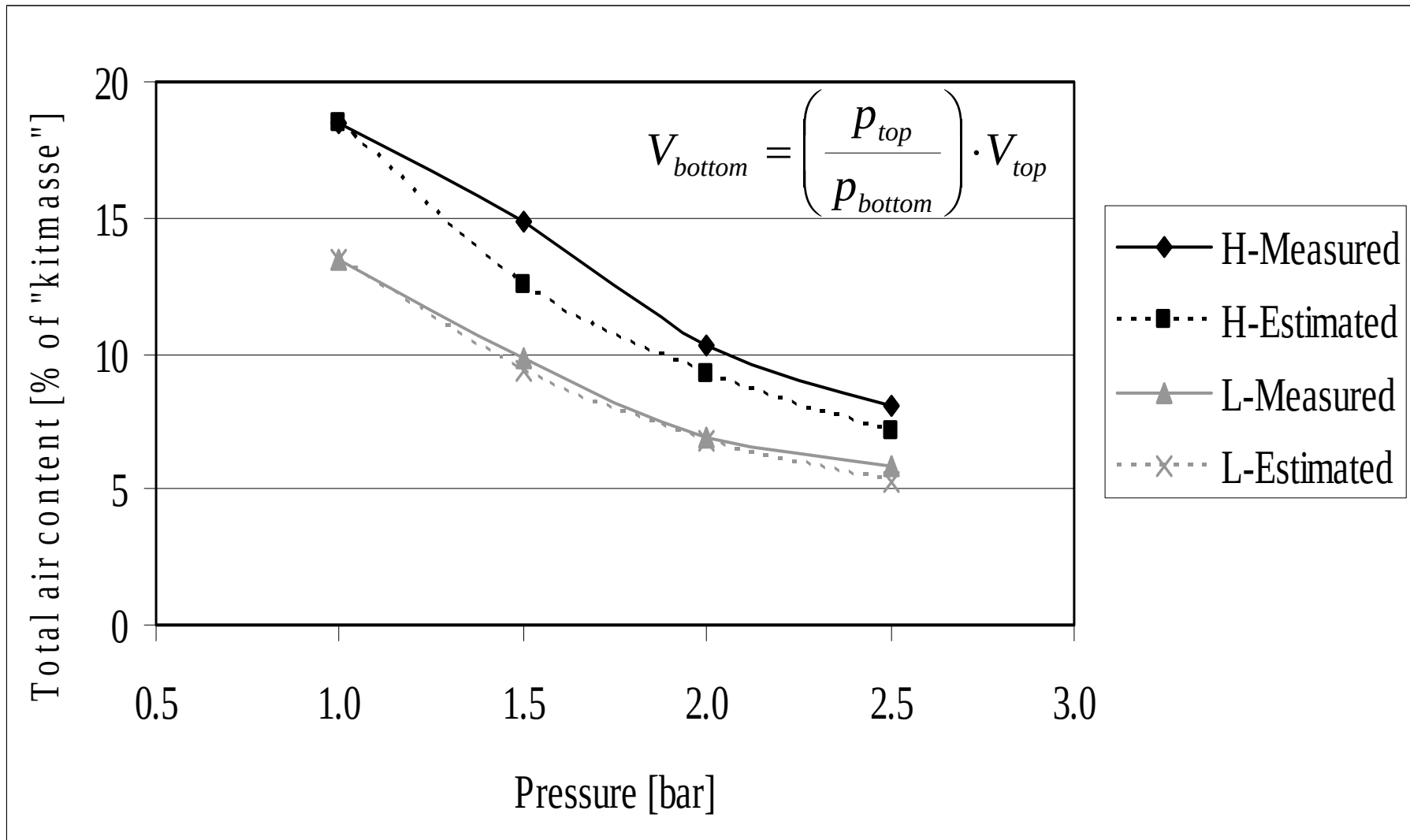
Expected Pressure Related Changes



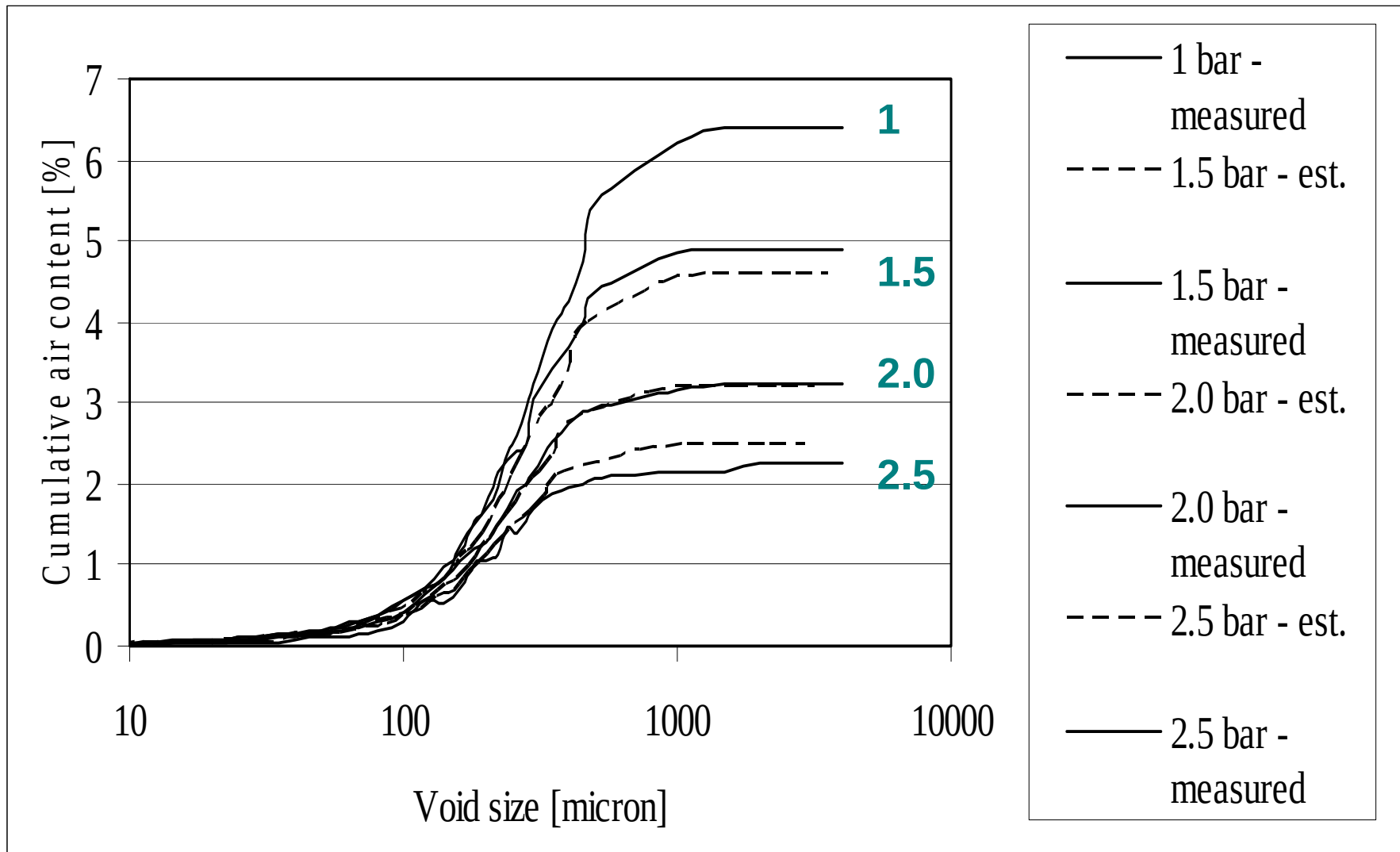
Pressure Related Changes of the Spacing Factor in **Laboratory** cured concretes



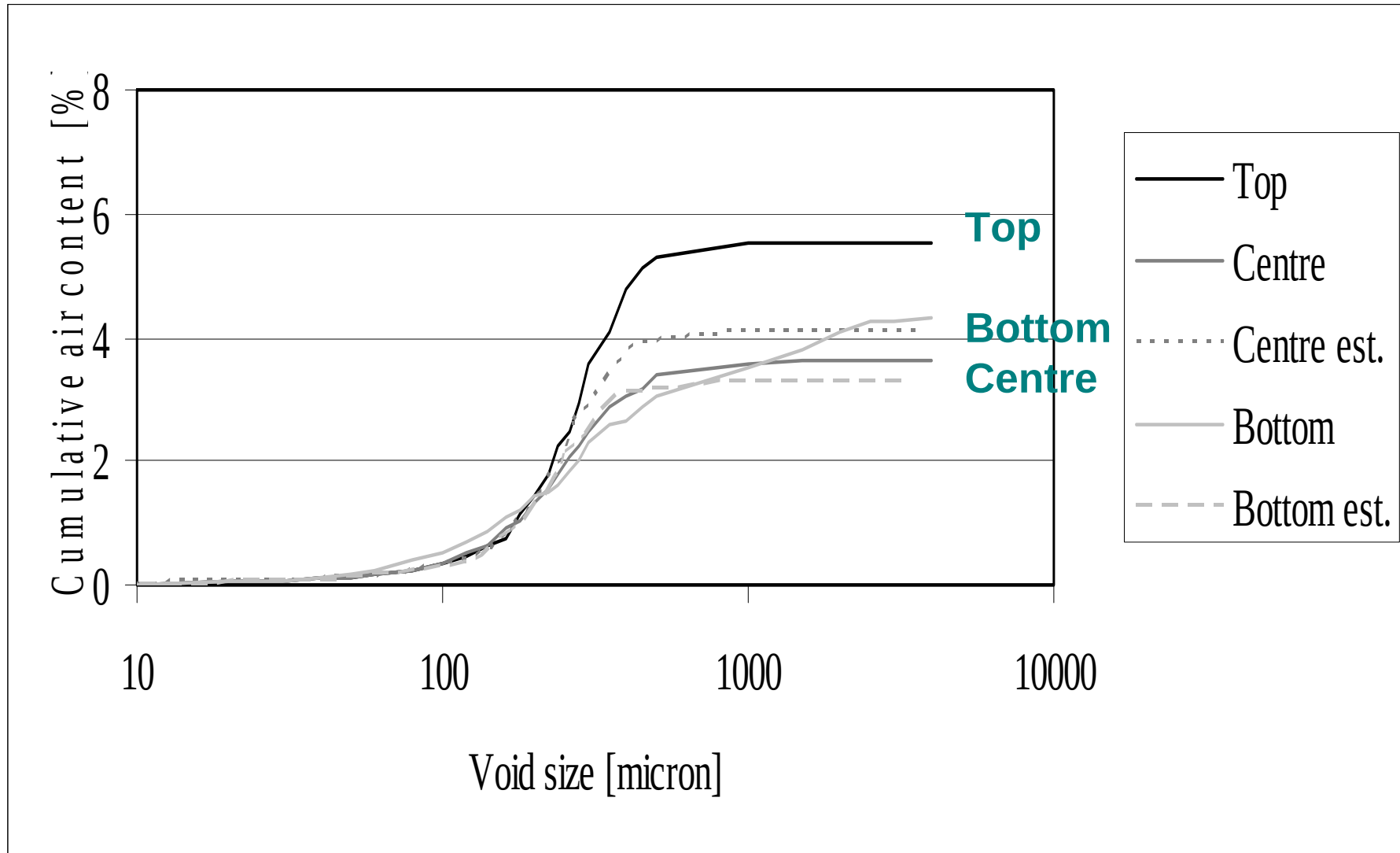
Total Air Content (% of paste + air), Mean of the Laboratory Cured Concretes



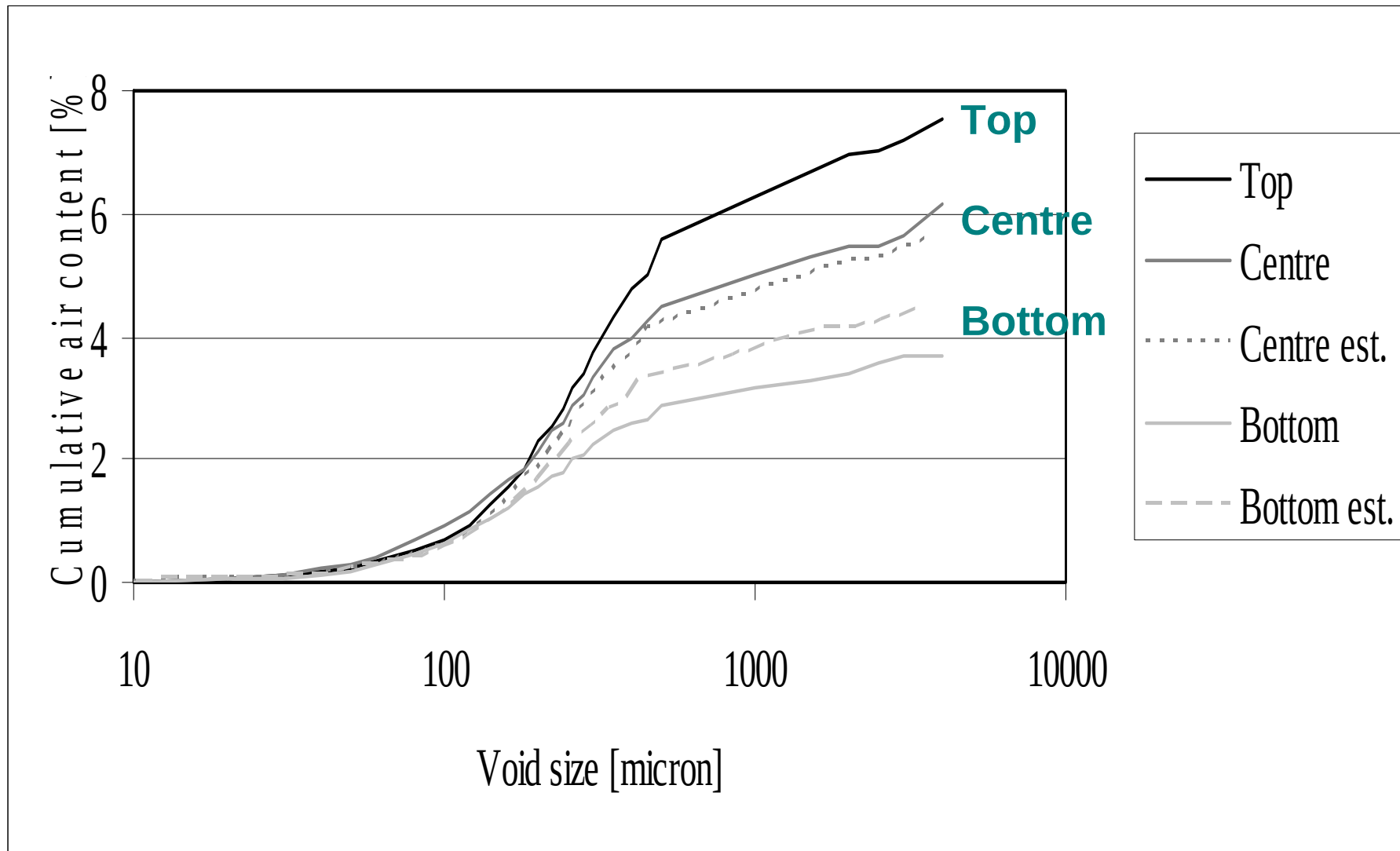
Measured and Estimated **Air Void Distribution**, **Laboratory** Cured Concrete, Mix H-B



Air Void Distribution in Full-scale Wall Casting Form Filled From Bottom



Air Void Distribution in **Full-scale** Wall Casting Concrete **Poured 0.5 Meter Above Surface**



Summary and Conclusions

Through laboratory castings of six concrete mixes, each hardened at four different pressures, the pressure related changes of the air void structure were examined

The results indicate that pressures related changes might be estimated by using Boyle-Mariottes law

Full-scale casting revealed that other factors than the form pressure influence the air void structure, e.g. the method of placement

References

Billberg, P.: Form pressure generated by self-compacting concrete, 3rd Int. Symp. Self-Compacting Concrete, 17-20 Aug 2003, Reykjavik, pp. 271-280

Acknowledgement

The full-scale wall castings were carried out as part of the work in the **Danish SCC Consortium**

The authors would like to thank for the access to the results

www.SCC-konsortiet.dk

ASTM C09.47

Minutes of Meeting June 12, 2006, e.g.

Blocking

- ASTM C 1621/C1621M-06 Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring - Approved
- Development of U-box and L-box methods stopped

Stability

TG for establishment of ASTM test method for dynamic stability established

Others

Proposed terminology to include in existing ASTM test methods to allow their use with SCC

Economy / Benefits / Environment

SCC - economical benefits?

Sverre Smeplass, Skanska Norge AS

Bård Pedersen, NorBetong AS

Why use SCC?

■ Increased productivity?

- Reduced manhours, reduced work force
- Reduced repair costs

■ Increased quality?

- Less flaws
- Smoother surfaces, less pores, improved surface durability

■ Improved working environment?

- Reduced noise
- Reduced back and arm wear

Why use SCC?

- SCC is normally the choice of the contractor:

....is it profitable?

Use of SCC

- Slabs
- High walls
- Restricted access
- High quality surfaces
- Concrete elements

Traditonal float plastering





Example, slab, 200 mm

■ Traditional procedure

- Float plastering: + NOK 100,- /m²
(alt. troweling: + NOK 70,- /m²)

■ SCC

- Increased concrete cost: + NOK 25,- /m²
- Reduced man hours: - NOK 5,- /m²
- Grinding: + NOK 20,- /m²

Potential saving: NOK 60,-/m²

(+ reduced production time)

Success criteria (1)

■ Robust concrete

- Sufficient amount of fines / filler
- Moderate cement content
- Moisture control
- Non-sensitive to normal variation in additive dosage

■ Formwork

- No leakages, well adapted details
- High quality panels for smooth surfaces
- Correct use of release agents
- Proper cleaning

Success criteria (2)

■ Well prepared concreting

- Formwork, sections and joints according to SCC properties
- Detailed filling plan
- Well adapted flowability and viscosity
- Delivery capacity and actual delivery
- Filling rate vs formwork pressure

■ Communication at site

- Competence in both ends
- Detailed specification (according to Euro Guideline)
- Visual control basis for corrections



..nice surfaces , bad panel sectioning

Altered responsibilities?

- More detailed concrete specification
- Increased risk for both contractor and concrete producer?
 - Bad result: Who is to blame?
- New European guidelines: a step towards a “clean cut” between contractor and concrete producer??

Example, major civil structure



Bjørvika Concrete Tunnel

AF Bjørvikatunnelen

■ Joint Venture between

- Skanska Norge AS (60%)
- Bam Civiël, Holland (20%)
- Volker Stevin, Holland (20%)

■ NOK 1,0 bill contract.

- (1 av 3 main contracts, total of > NOK 3.0 bill.)

■ Approx. 70000 m³ structural concrete

■ Completed 2010 / 2011

Bjørsvika Concrete Tunnel, typical data

- 6 elements, each 112 m long
- Widths 28-41 m
- Each element consists of 5 sections
- Top and bottom slabs 1.20 - 1.40 m, walls 1.00 m
- Pre-fabrication at Hanøytangen (Bergen), towed to Oslo

.....

- 2 of 6 elements almost completed (June 2006)



March 2006



May 2006

Concrete specification (1)

- CEM I
- $w/b < 0.45$
- "C40"
- 30-65% PFA (by clinker weight), $k=0.7$
- 4-8% CSF (by clinker weight), $k=2.0$
- Frost resistance (!)
- Density 2450 kg/m^3 (!)

Concrete specification (2)

- Crack index < 0.75 (tensile stress / tensile strength)
- PP-fibers for fire protection in lower 400 mm of tunnel ceiling
- Comprehensive test- and documentation programme
 - General material documentation, data input for FEM stress analysis, and conventional site control

Mix design challenges

- High concrete density
- Locally congested reinforcement in walls
 - Pump hoses must be pre-placed
 - Difficult to lower pokers
 - SCC?
- Minimized heat of hydration
 - Slow strength development
 - Late demoulding - affecting production cycles ?

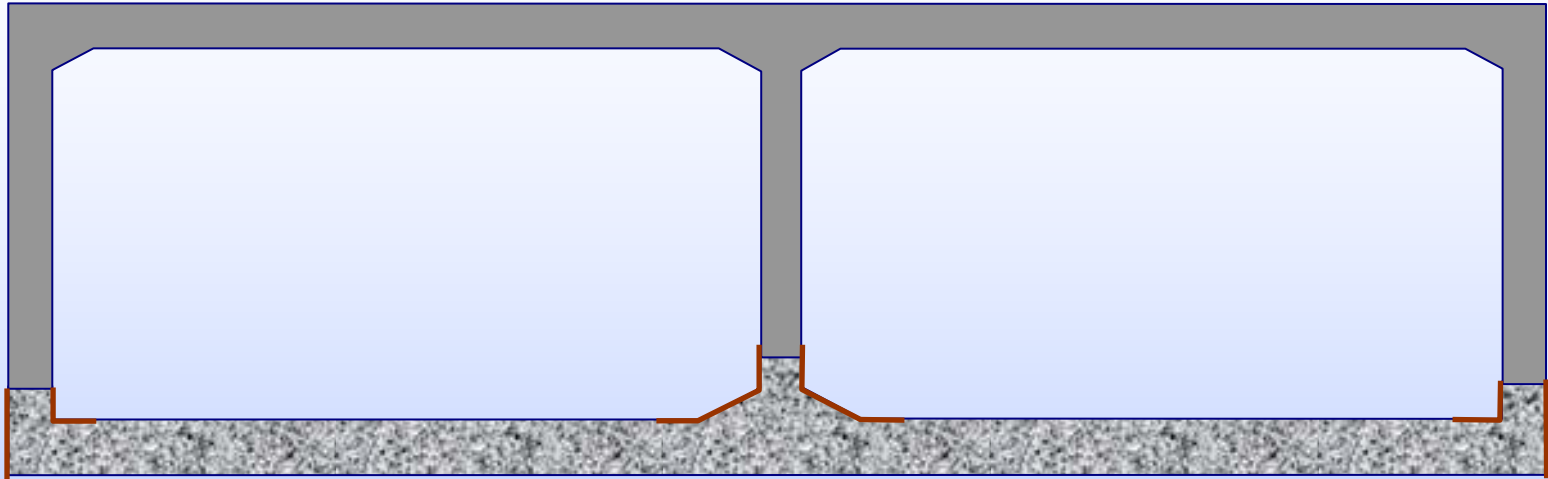
Mix Design Solutions

- PFA ground with HS clinker to CEM II B/V (Norcem)
 - Improved logistics
 - Improved workability / stability
 - Effect on heat of hydration?
- High quality natural sand (Årdal), high fines content ($\sim 10\% < 0.125 \text{ mm}$)
 - Increased viscosity / stability
 - Increased matrix volume; improved flow
- High density crushed rock (Eklogitt $\sim 3120 \text{ kg/m}^3$)

.....

Mix design in close cooperation between Skanska and NorBetong

Workability



- Bottom slab and upper layer of top slab: SF 500-600 mm (vibrated)
- Walls: SU 650- 720 mm (SCC)
 - Pre-placed pipes and hoses
 - Approx. 5 meters between pipe outlets
 - Rate 1 m/h (50m³/h)
- PP-fiber concrete in top slab: slump 240 mm (vibrated)

SCC - Effect on costs for the concrete tunnel

- Limited additional concrete costs
 - SCC mix design close to ordinary low heat concrete
 - Minor changes in production procedures and production control
- Reduced man hours
 - Saving approx. 0.1h/m³
- Repair almost eliminated
 - Saving approx. 0.05h/m³
- Positive total balance!

Concrete Tunnel - SCC surfaces



Preliminary experience

- Very reliable concrete delivery
 - 1300 m³ continuous pours without critical stops
 - 50-60 m³/h during 30 hours
 - Impressive production statistics
- Extremely stable workability
 - SCC more robust than vibrated concrete
 - Low form pressure
 - No visible layers

SCC – economy, summary

- Additional material cost will normally exceed man hour savings in the concreting process
- A positive balance can be achieved
 - Simplified solutions
 - Reduced repair and surface treatment costs
- A robust, cost optimized technology is crucial

SCC and the Working Environment

- results from the SCC-Consortium



Co-operation between:

- Danish Technological Institute
- Danish Centre for the Working Environment
- MT Højgaard A/S

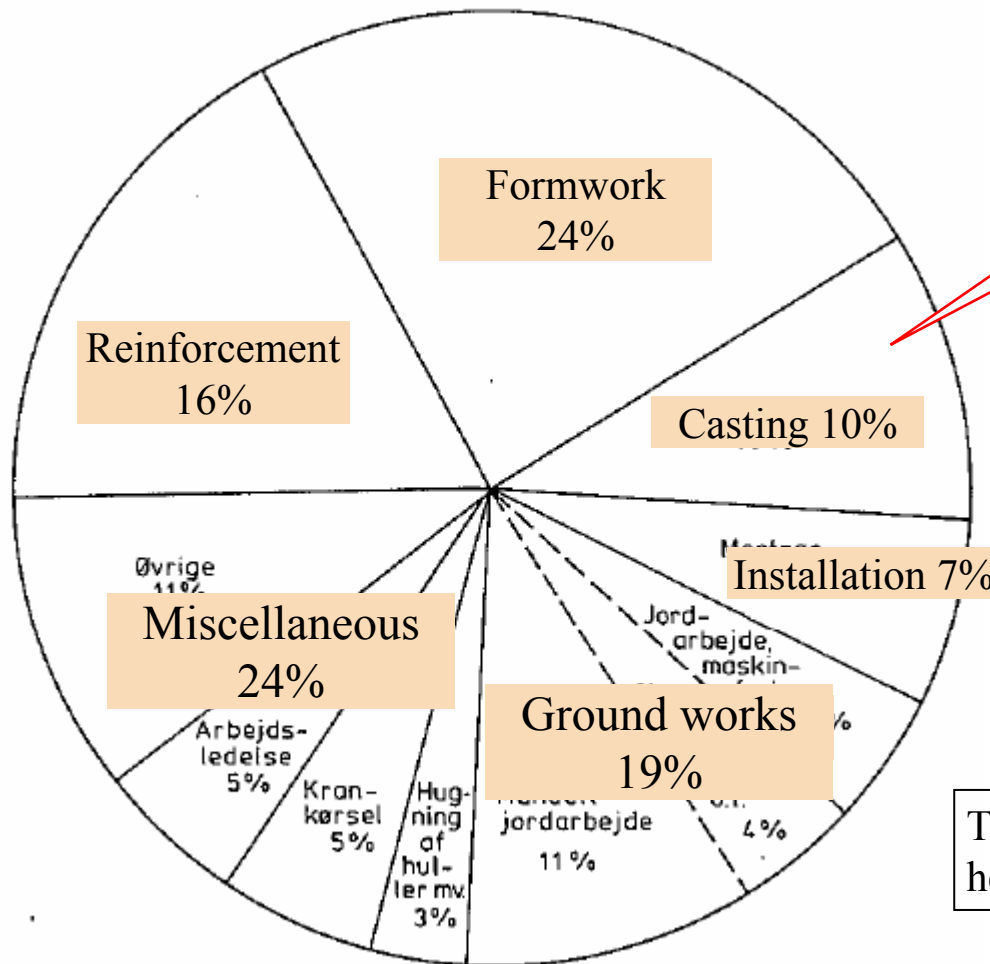


What are the impacts of SCC on the working environment?

- Vibrations are reduced (most significant on the building site)
- Noise level is reduced (most significant in the precast plant)
- Fewer unhealthy working positions and better ergonomics (most significant on the building site in connection with vertical casts)
- Chemicals and dangerous substances
- Background:
 - Brite EuRam “Rational Production...SCC”, 1997-2000
 - Brite EuRam “TESCOP”, 1997-2000
 - Danish investigation of health and safety in the construction industry, DTU, 1979-1981

Introduction

Concrete workers average occupation

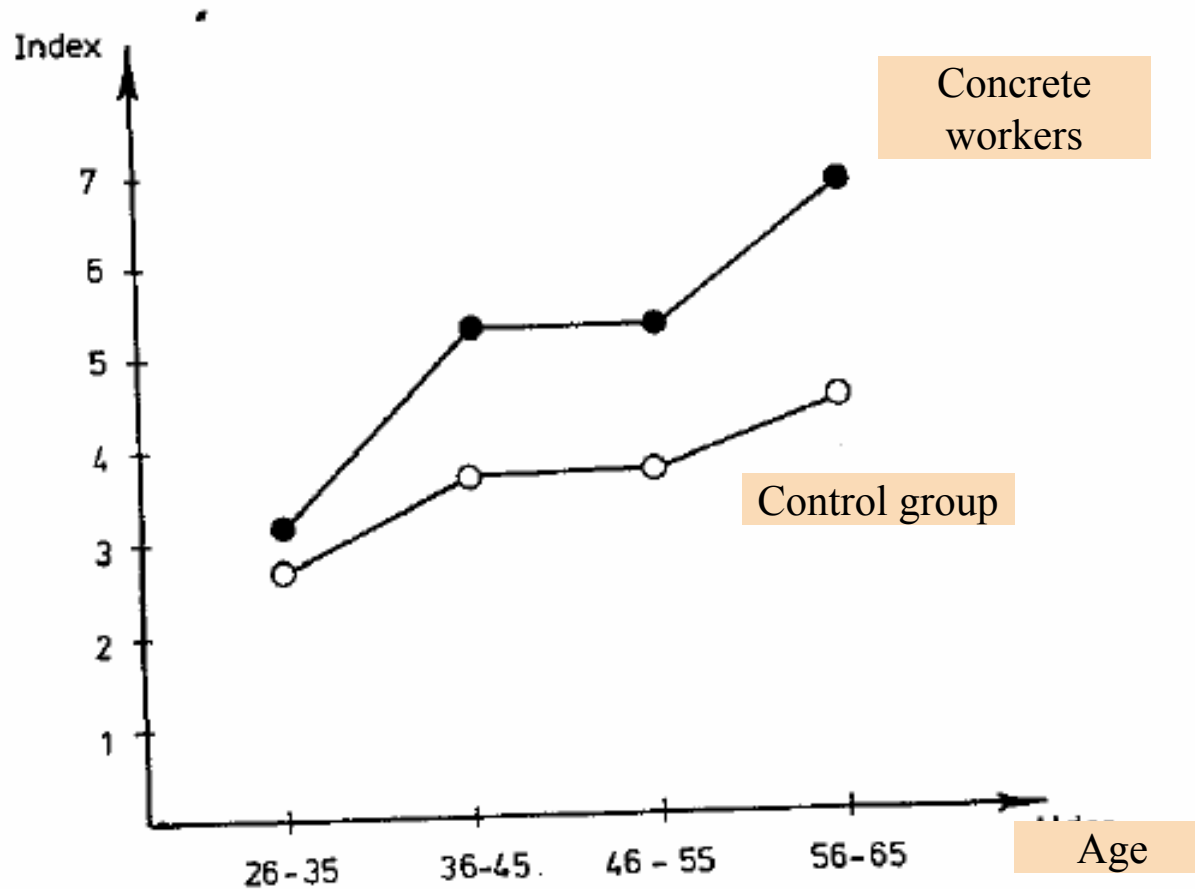


SCC has impact on this part

Taken from Danish project on concrete workers health and safety, DTU, 1979-1981.

Introduction

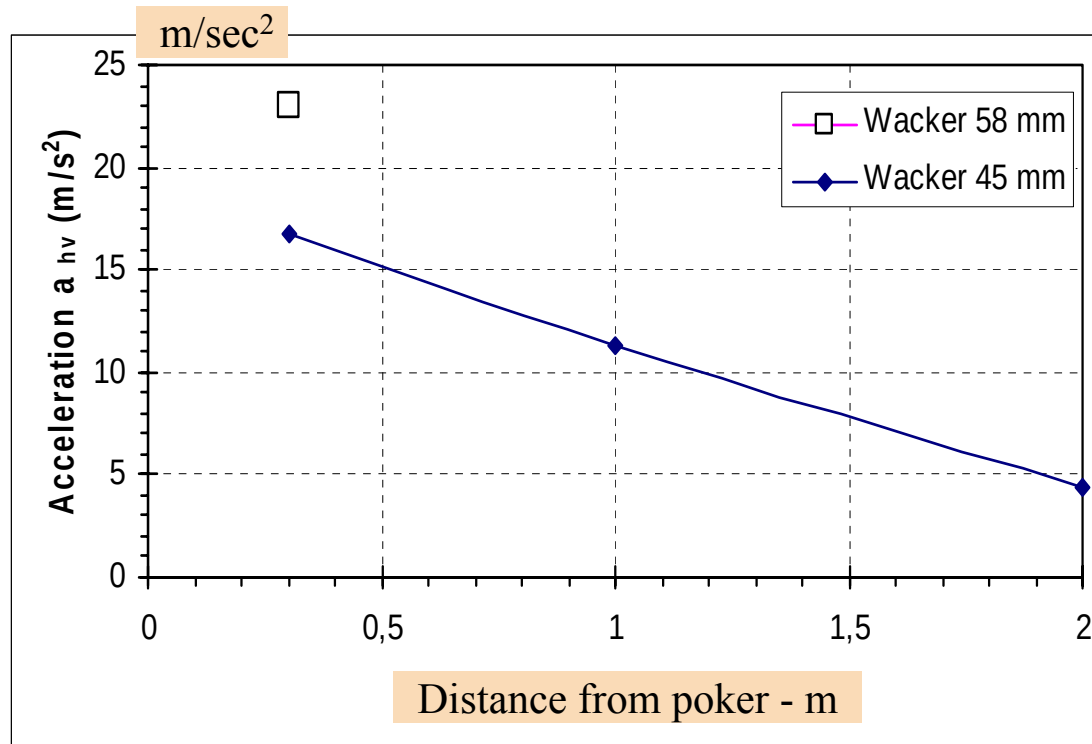
Concrete workers do wear down more than the public in general



Taken from Danish project on concrete workers health and safety, DTU, 1979-1981.

Introduction

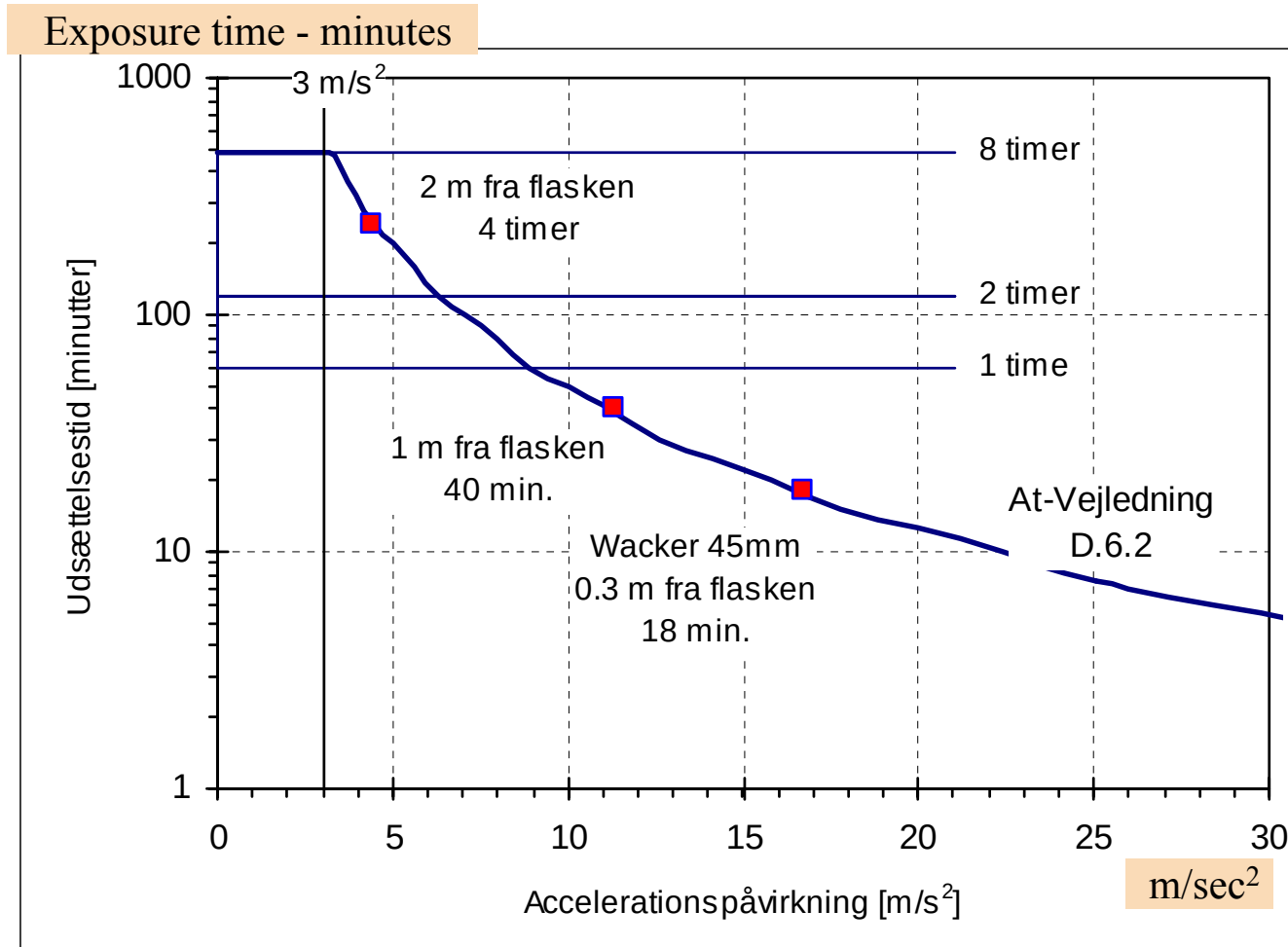
Vibration impact on hand-arm from poker vibration



- Accelerometer measurements
- Vibrator hanging from scaffold
- Resulting acceleration calculated from x, y and z components
- Wacker declare that acceleration impact is 4 m/s²

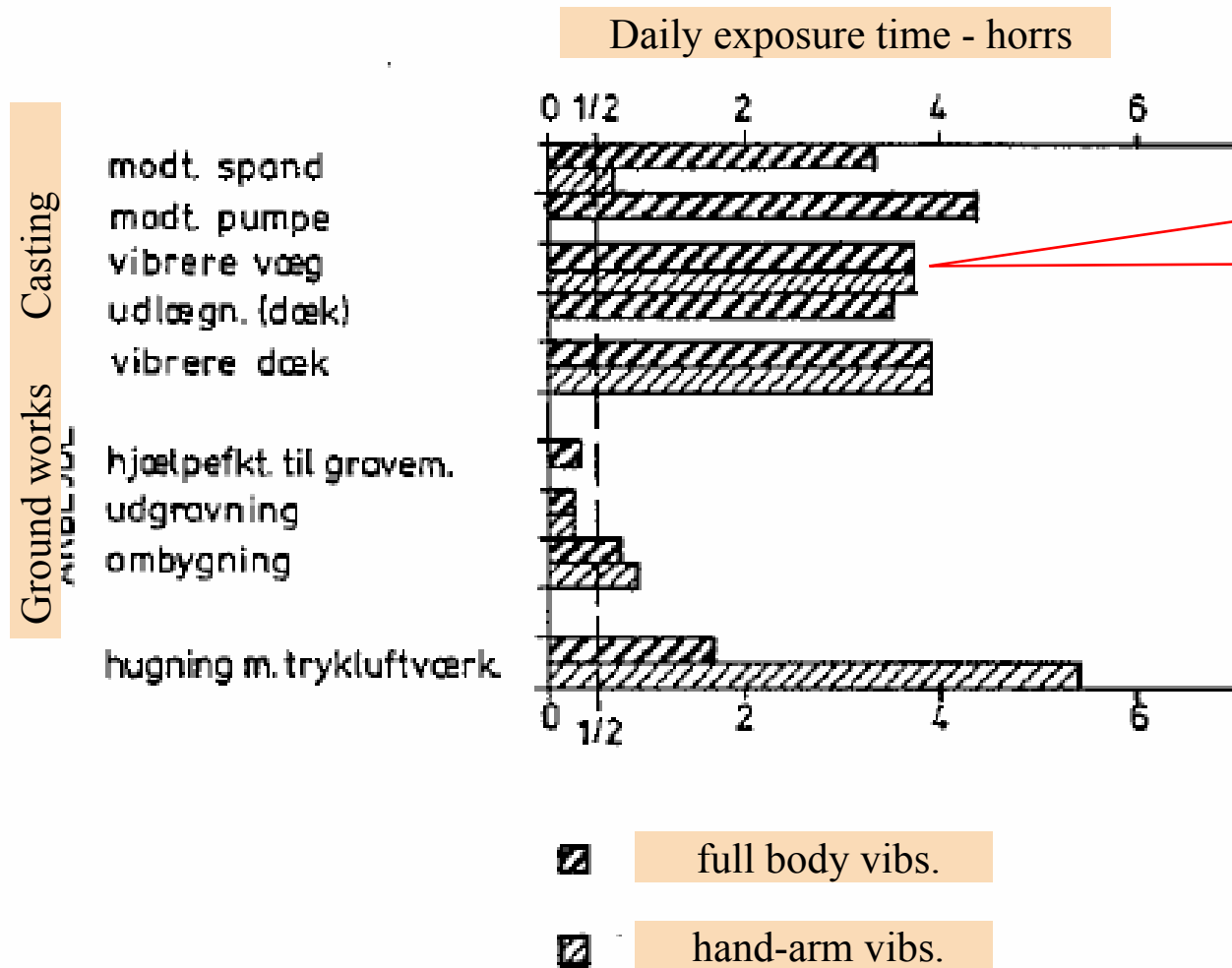
Vibration

Allowable exposure times



Vibration

Allowable exposure times



**Observation for wall casting:
Approx. 2 hours exposure**

Taken from Danish project on
concrete workers health and
safety, DTU, 1979-1981.

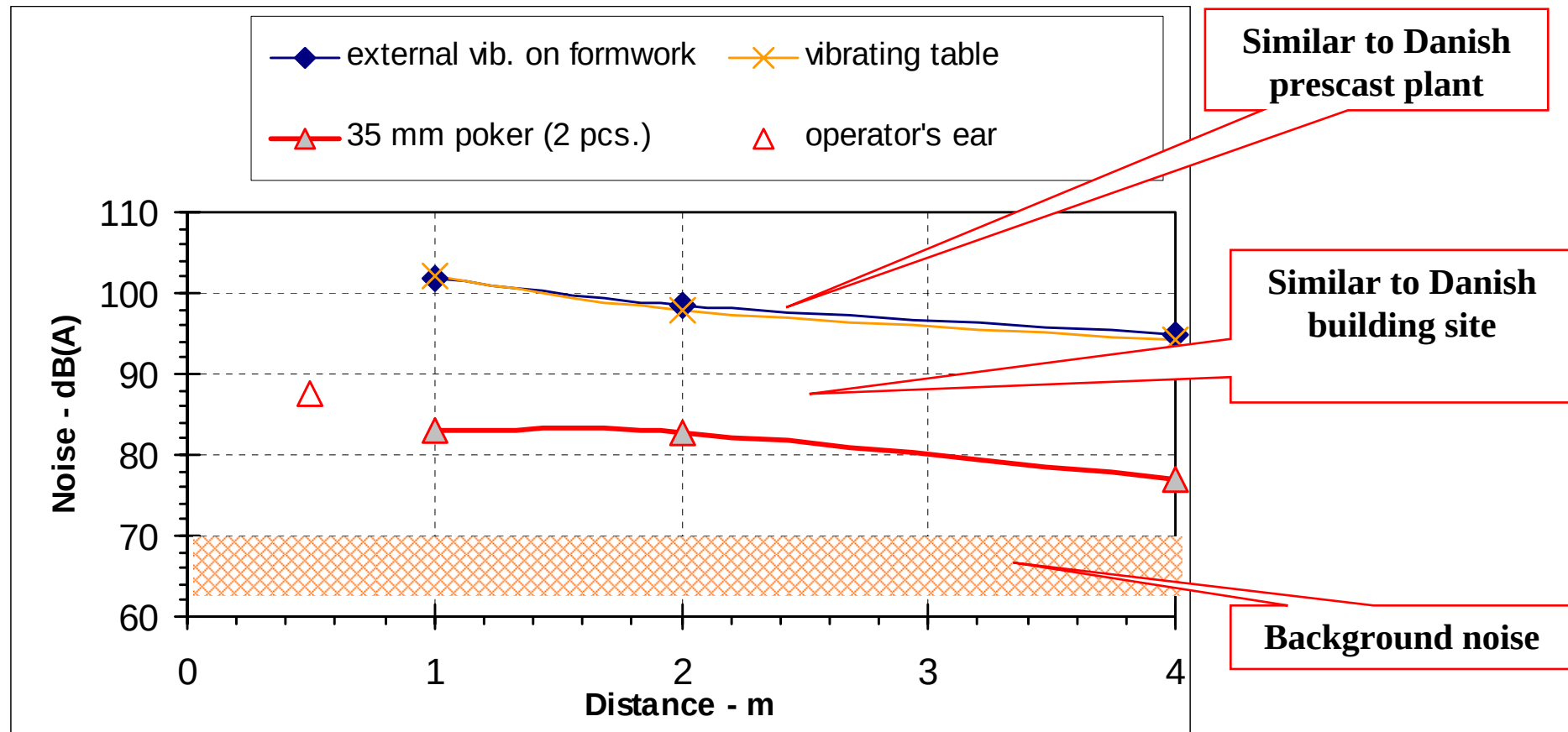
Vibration

Conclusions - 1

- Exposure to vibrations from handheld equipment is a health risk for concrete workers.
- Increased risk of numbness and poor blood circulation in fingers/hands.
- Limit of 3 m/sec² is easily exceeded with poker vibrators.
- However, pistol type poker vibrator with handle (for horizontal castings) are less strenuous.
- Avoiding compaction with vibrators will improve the working environment significantly.

Conclusions

Noise measurements



Taken from Brite EuRam SCC project, 1997-2000, Results obtained at University of Paisley.

Noise

Conclusions - 2

- In a precast plant form vibrators generate excessive noise throughout the building.
- Level around 95-100 dB(A) under vibration, which means less than one hour daily exposure time allowed.
- Omitting vibration reduces noise level from down to around 70-80 dB(A).
- Only need for ear protection when noisy equipment are used (electric saw, drilling, grinding, etc.)
- Leaving out the noise from vibration improves the working environment significantly in the precast plant.
- However, still a short vibration is sometimes used with SCC.

Conclusions

Conclusions - 3

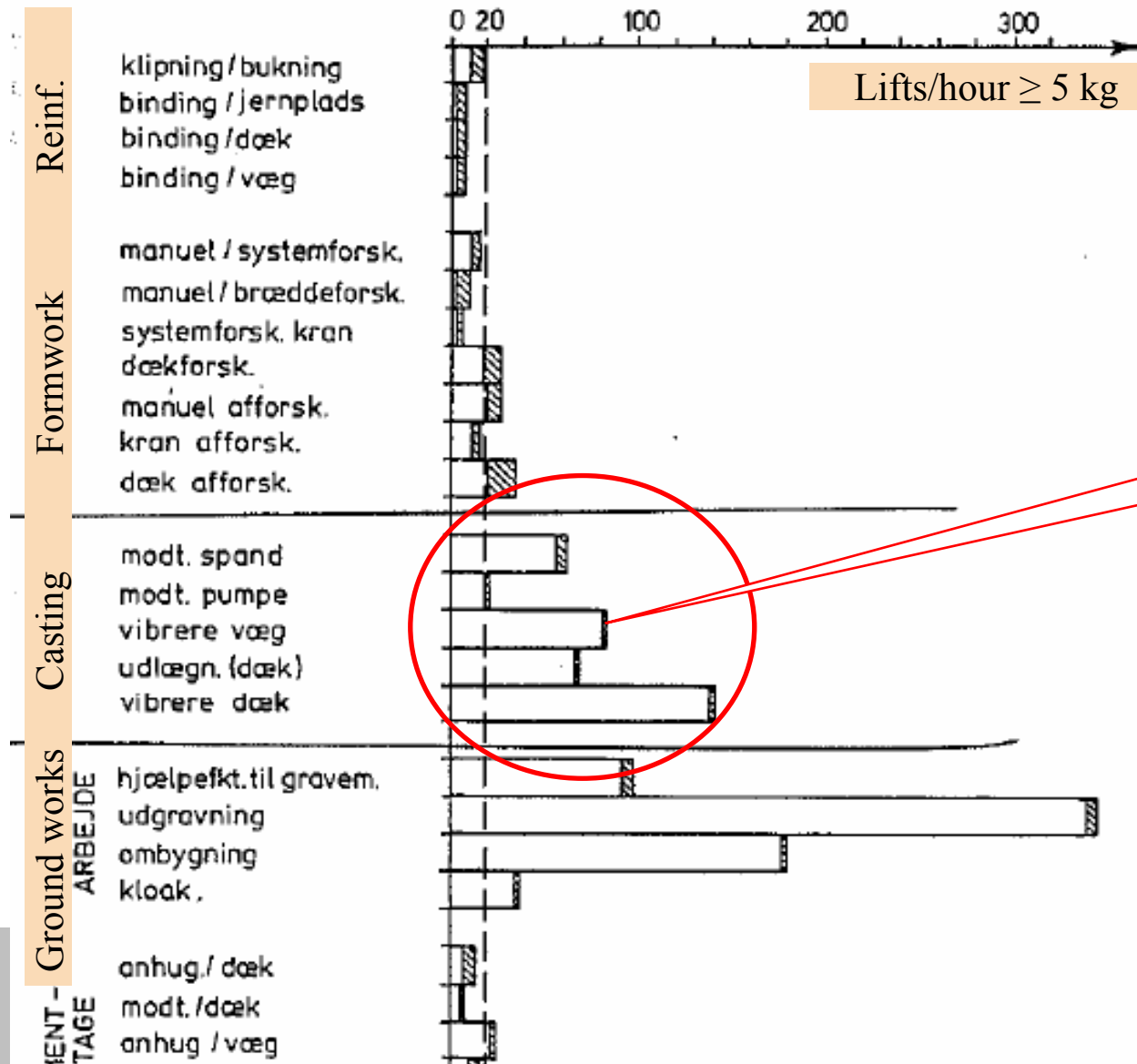
- At building site the limit of 85 dB(A) is clearly exceeded for all the workers in the vicinity of the casting. Thus, ear protection is mandatory.
- Max allowed exposure time is around 2 hours per day.
- Omitting vibration at the building site reduces noise level from 90-95 dB(A) to around 85 dB(A). 10 dB(A) increase is felt as a doubling of the sound.
- Therefore, avoiding compaction with vibrators will improve the working environment significantly at the building site even though noisy operations are still taking place (heavy machines, pumps, etc.).

Conclusions

Ergonomics

- **What are the important issues?**
 - heavy lifts of equipment and building materials
 - pushing and pulling (risk of sudden unexpected movements/impacts)
 - many repetitions
 - unhealthy and unpleasant working positions (crouched/hunched)
- **Difficult to measure and quantify**
- **Differs from person to person (not objective)**

Lift of equipment and materials



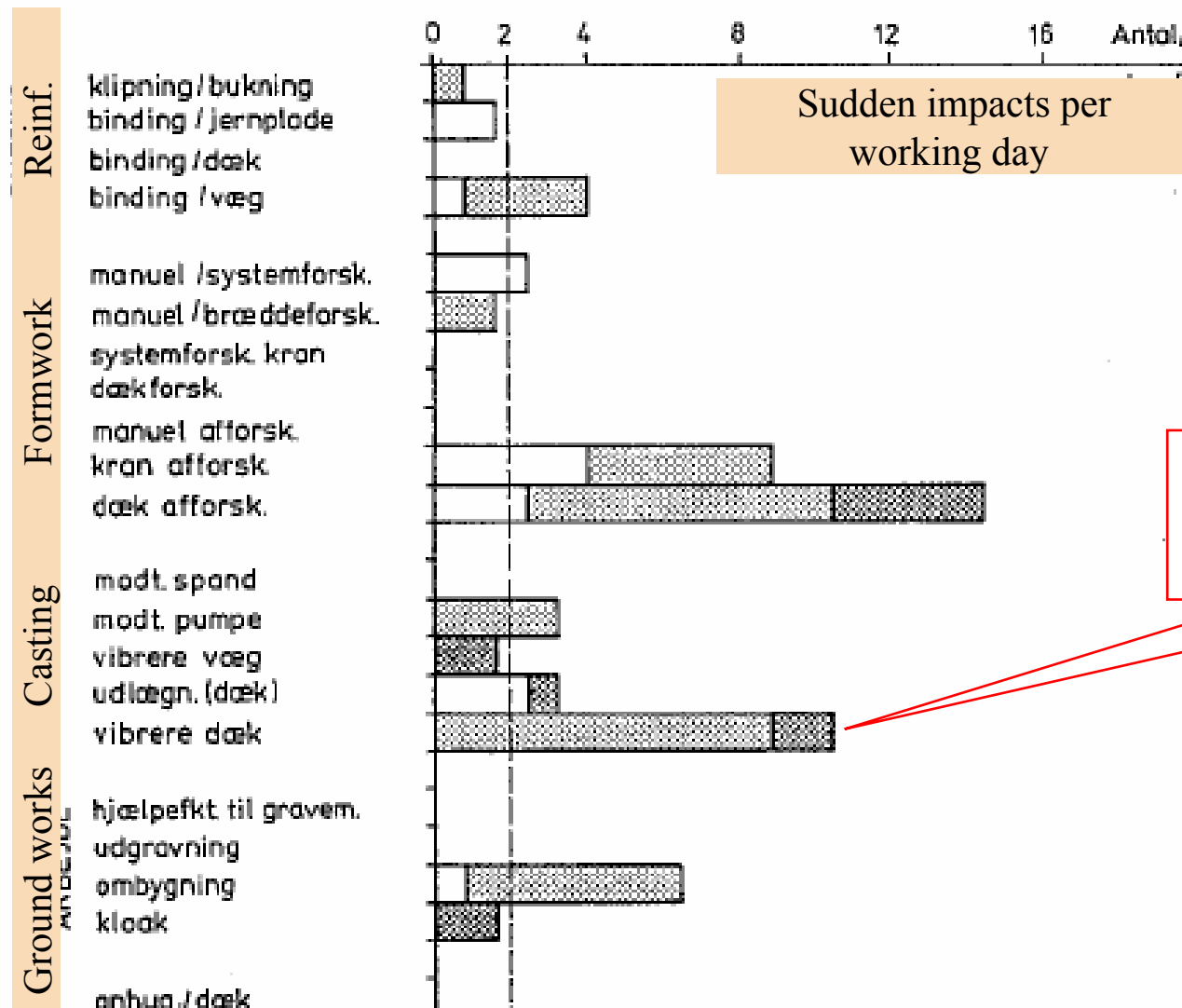
**Observation for wall casting:
Approx. 86 lifts/hour in
connection with vibration**

Taken from Danish project on
concrete workers health and
safety, DTU, 1979-1981.

Ergonomics

DTI, Concrete Centre
Claus Vestergaard Nielsen

Lift of equipment and materials



Sudden impacts per working day

Vibration of floors, where vibrator hose gets stuck.

Taken from Danish project on concrete workers health and safety, DTU, 1979-1981.

Ergonomics

Ergonomics for wall castings with traditional vibration

- Many moderately heavy lifts.
- Bending over and lifting at the same time, resulting in torsion of the back.
- Difficult to obtain good and secure base for your feet.
- All in all very stressful working conditions for the human body.
- Plus vibration and noise impact.

[IMVI_0538_pumpe.AVI](#)

[IMVI_0540_arb_stillinger.AVI](#)



Video from MT Højgaard site at DR-byen, Copenhagen, June 2005.

Conclusions - 4

- **Concreting has large impact on back and joints due to heavy lifts and unhealthy working positions.**
- **SCC reduces the impact and thereby the increased wearing down of concrete workers by leaving out some of the stressful working positions.**
- **The SCC effect on the ergonomic working environment is most pronounced for wall castings.**

Conclusions

More information

- www.SCC-konsortiet.dk
- www.VoSCC.dk (only in Danish)
- www.NordicSCC.net
- Claus.V.Nielsen@Teknologisk.dk



Copenhagen 19 June 2006.

Cost savings by use of SCC in
floors.

It is not possible to give one strait answer for savings using SCC.

There is a lot of different combinations in

- Surface treatment
- Floor thickness
- Weather conditions
- Specification of surface concerning tolerance of level.
- Size of floor area.
- Ect.

The following choice has been made.

The economical analyse will be based on.

1000 m² of floor/slab

Thickness vary from 10 cm to 40 cm.

Surface treatment vary from none to smoot grinding.

Weather condition won't be a part of this paper.

Special surface treatment developed as a part of using SCC to be mentioned.

Risk to be mentioned.

SCC work.



Figure 11.1 Levelling SCC with a skip float

After-treatment such as the use of steel trowel finishing or float-finishing may be carried out as vibrated concrete. However, if the SCC shows thixotropic stiffening, judging the correct time to start this part of the finishing can be difficult.

Concrete price level.

Concrete type	Standard	SCC	SCC
	Price average	%	Price
	EUR/m3		EUR/m3
C 20 P	85	17,1	99
C 25 P	87	16,4	102
C 30 P	91	15,6	105
C 35 P	95	14,9	109
C 30 M	103	9,5	113

Figures used.

Concrete as "we know it" without surface treatment.

Euro
Area
Thicknes

7,45 DKK
1000 m2
10 cm

Activity			manhour unit	Materials Eur/unit	Eq. No. Of Manhour	Manhour EUR 40	Materials EUR	Equip. EUR
Insulation	m2	1000	0,05	5	50	2.000	5.000	-
Formwork along edges	m2	20	5	27	100	4.000	540	-
Reinforcement 2 o/oo	ton	3,04	12	670	36	1.459	2.037	-
Concrete deliver and casting	m3	100	0,4	85	40	1.600	8.500	-
Concrete pump	m3	100			13	-	-	1.300
Vibration eq.	m3	100			2	-	-	200
Claze with steel towel	m2	0	0,08		-	-	-	-
Hire eq.	m2	0			1	-	-	-
Evaporation protection	m2	1000	0,03	0,5	30	1.200	500	-
						256	10.259	16.577
						Total		28.336

Figures used in calc.

SCC Without surface treatment.

Euro
Area
Thicknes

7,45 DKK
1000 m2
10 cm

Activity			manhour unit	Materials Eur/unit	Equi No. Of Manhour	Manhour EUR 40	Materials EUR	Equipment EUR
Insulation	m2	1000	0,05	5	50	2.000	5.000	-
Formwork along edges	m2	1	3	27	3	120	27	-
Reinforcement 2 o/oo	ton	3,04	12	670	36	1.459	2.037	-
Concrete deliver and casting	m3	100	0,15	99	15	600	9.900	-
Concrete pump	m3	100			13	-	-	1.300
Vibration eq.	m3	100			0	-	-	-
Claze with steel towel	m2	1000	0		-	-	-	-
Hire eq.	m2	1000			0	-	-	-
Evaporation protection	m2	1000	0,03	0,5	30	1.200	500	-
Grinding first time 2 to 3 mm	m2	1000			0			-
Grinding second time 1 to max	m2	1000			0			-
						134	5.379	17.464
						Total		24.143

Concrete floor without surface treatment.
1000 m²

	10	15	20	25	30	35	40	cm
C 20 P	28.336	38.154	47.972	57.790	67.608	77.426	87.244	EUR
C 25 P	28.536	38.454	48.372	58.290	68.208	78.126	88.044	EUR
C 30 P	28.936	39.054	49.172	59.290	69.408	79.526	89.644	EUR
C 35 P	29.336	39.654	49.972	60.290	70.608	80.926	91.244	EUR
C 30 M	30.136	40.854	51.572	62.290	73.008	83.726	94.444	EUR

SCC without surface treatment.

	10	15	20	25	30	35	40	cm
C 20 P	24.143	31.791	39.439	47.087	54.735	62.383	70.031	EUR
C 25 P	24.443	32.241	40.039	47.837	55.635	63.433	71.231	EUR
C 30 P	24.743	32.691	40.639	48.587	56.535	64.483	72.431	EUR
C 35 P	25.143	33.291	41.439	49.587	57.735	65.883	74.031	EUR
C 30 M	25.543	33.891	42.239	50.587	58.935	67.283	75.631	EUR

Savings without surface treatment. 1000 m²

	10	15	20	25	30	35	40	cm
C 20 P	4.193	6.363	8.533	10.703	12.873	15.043	17.213	EUR
C 25 P	4.093	6.213	8.333	10.453	12.573	14.693	16.813	EUR
C 30 P	4.193	6.363	8.533	10.703	12.873	15.043	17.213	EUR
C 35 P	4.193	6.363	8.533	10.703	12.873	15.043	17.213	EUR
C 30 M	4.593	6.963	9.333	11.703	14.073	16.443	18.813	EUR

Figures used in calc.

Concrete as "we know it" with surface treatment.

Euro
Area
Thicknes
Concrete C 30 M

7,45 DKK
1000 m2
40 cm

Activity			manhour unit	Materials Eur/unit	Eq. No. Of Manhour	Manhour EUR 40	Materials EUR	Equip. EUR
Insulation	m2	1000	0,05	5	50	2.000	5.000	-
Formwork along edges	m2	80	5	27	400	16.000	2.160	-
Reinforcement 2 o/oo	ton	12,16	12	670	146	5.837	8.147	-
Concrete deliver and casting	m3	400	0,4	103	160	6.400	41.200	-
Concrete pump	m3	400			13	-	-	5.200
Vibration eq.	m3	400			2	-	-	800
Claze with steel towel	m2	1000	0,1		100	4.000	-	-
Hire eq.	m2	1000			2	-	-	2.000
Evaporation protection	m2	1000	0,03	0,5	30	1.200	500	-
						886	35.437	57.007
						Total		100.444

Figures used in calc.

SCC With surface treatment.

Euro
Area
Thicknes
Concrete C 30 M

7,45 DKK
1000 m2
40 cm

Activity			manhour unit	Materials Eur/unit	Equi No. Of Manhour	Manhour EUR 40	Materials EUR	Equipmen EUR
Insulation	m2	1000	0,05	5	50	2.000	5.000	-
Formwork along edges	m2	1	3	27	3	120	27	-
Reinforcement 2 o/oo	ton	12,16	12	670	146	5.837	8.147	-
Concrete deliver and casting	m3	400	0,2	113	80	3.200	45.200	-
Concrete pump	m3	400			13	-	-	5.200
Vibration eq.	m3	400			0	-	-	-
Claze with steel towel	m2	1000	0		-	-	-	-
Hire eq.	m2	1000			0	-	-	-
Evaporation protection	m2	1000	0,03	0,5	30	1.200	500	-
Grinding first time 2 to 3 mm	m2	1000			4			4.000
Grinding second time 1 to max 2 mn m2	m2	1000			3			3.000
						309	12.357	58.874
								12.200
						Total		83.431

Concrete floor with surface treatment

	10	15	20	25	30	35	40	cm
C 20 P	34.336	44.154	53.972	63.790	73.608	83.426	93.244	EUR
C 25 P	34.536	44.454	54.372	64.290	74.208	84.126	94.044	EUR
C 30 P	34.936	45.054	55.172	65.290	75.408	85.526	95.644	EUR
C 35 P	35.336	45.654	55.972	66.290	76.608	86.926	97.244	EUR
C 30 M	36.136	46.854	57.572	68.290	79.008	89.726	100.444	EUR

SCC floor with surface treatment

	10	15	20	25	30	35	40	cm
C 20 P	31.343	39.091	46.839	54.587	62.335	70.083	77.831	EUR
C 25 P	31.643	39.541	47.439	55.337	63.235	71.133	79.031	EUR
C 30 P	31.943	39.991	48.039	56.087	64.135	72.183	80.231	EUR
C 35 P	32.343	40.591	48.839	57.087	65.335	73.583	81.831	EUR
C 30 M	32.743	41.191	49.639	58.087	66.535	74.983	83.431	EUR

Savings with surface treatment. 1000 m²

	10	15	20	25	30	35	40	cm
C 20 P	2.993	5.063	7.133	9.203	11.273	13.343	15.413	EUR
C 25 P	2.893	4.913	6.933	8.953	10.973	12.993	15.013	EUR
C 30 P	2.993	5.063	7.133	9.203	11.273	13.343	15.413	EUR
C 35 P	2.993	5.063	7.133	9.203	11.273	13.343	15.413	EUR
C 30 M	3.393	5.663	7.933	10.203	12.473	14.743	17.013	EUR

Advantage contra disadvantage. Using SCC in floors.

- **Advantage**

- Cost saving
- Noise reduction
- Faster (less manhour)
- Ect.

- **Disadvantage.**

- Overall level more difficult to obtain
- Surface contains airbubble after grinding.
- More sensitive if concrete aren't delivered as planned.
- Evaporation protection more difficult.
- Insulation must be "protected" against oplit

SCC surface without grinding.



Same after grinding one time.



Insulation must be kept in position or it will float.



Quality of concrete delivery and casting.



SCC floor after treatment as mentioned below to be used as final surface

EverCrete® dybdeimprægnering

Diamantslibeprocesser

DBE Microspartel

Micopur W top mat – poreforsegler

Steifix 50 poreforsegler

Steifix 60 natursæbe

Price level 34 EUR

Final surface.



Production / Execution

Production and execution of SCC - for Industrial Construction

Mats Emborg

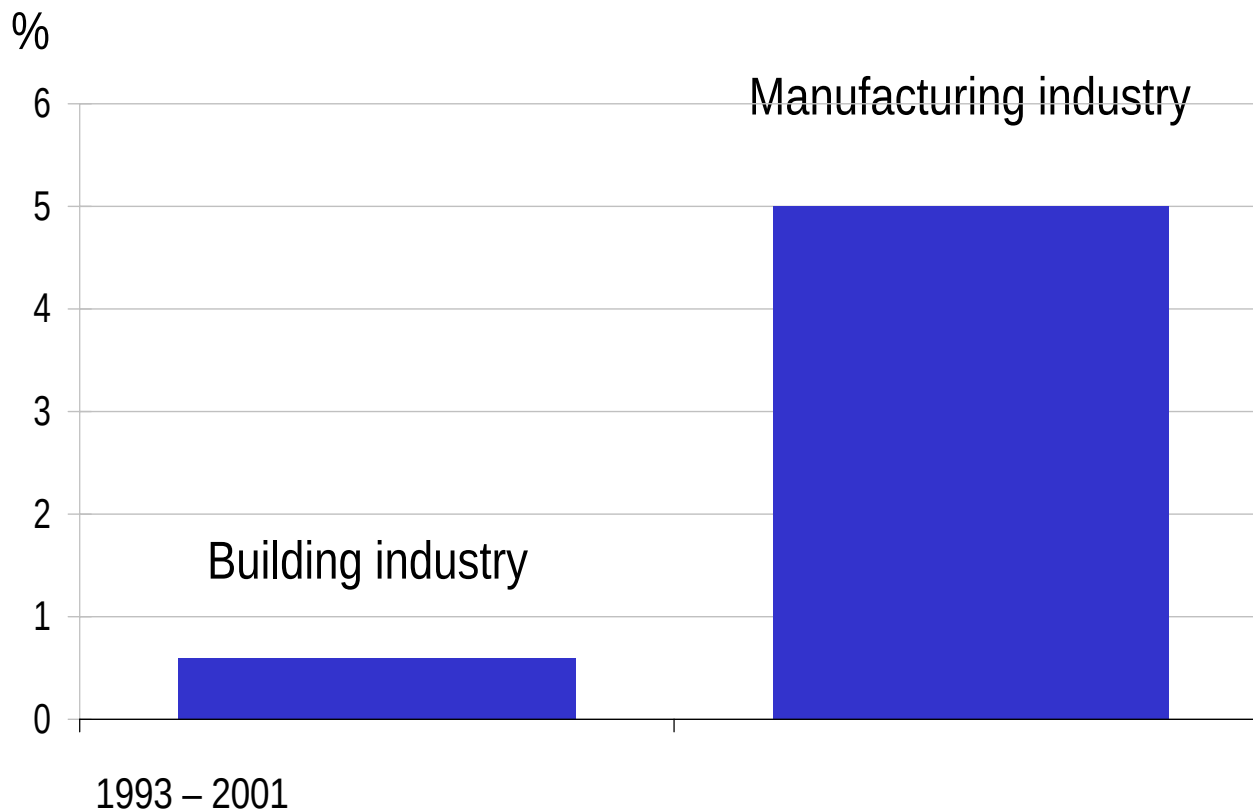
Betongindustri AB,
Luleå University of Technology
Sweden



Insufficient productivity increase



Productivity increase / year





The solution...

Assembly line/
Conveyor belt

Standardisation

Industrial construction

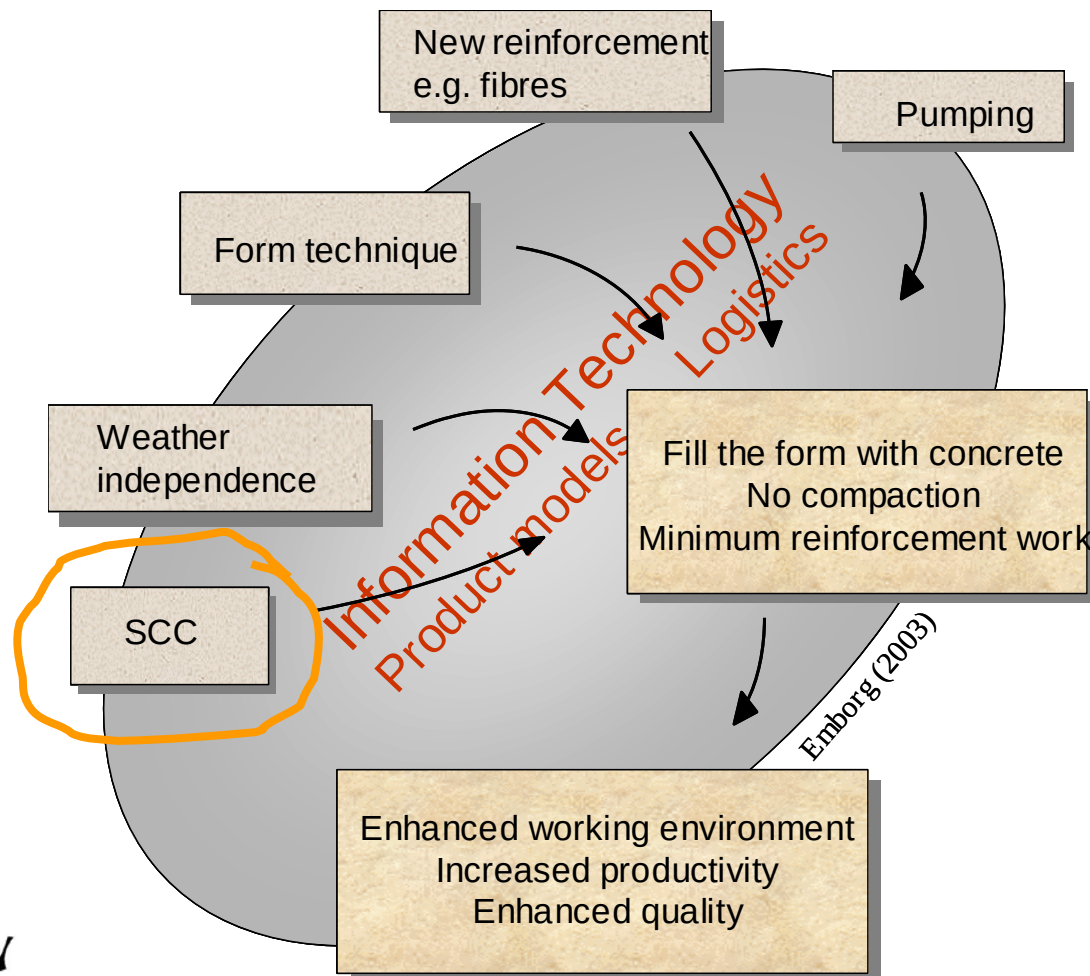
Lean Construction

Mechanization

Prefabrication

Industrialisation

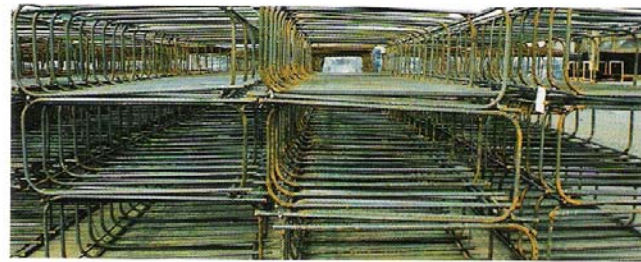
- with cast in place concrete



Reinforcement

- Large share of total construction costs

With prefabrication they are reduced



Exempel på monteringsvetsad armeringsbeter.



Reinforcement



The Bamtec system

Enormous decrease of fixing time
More effective utilization of reinforcement



Weather independence

- an important factor for an industrial process



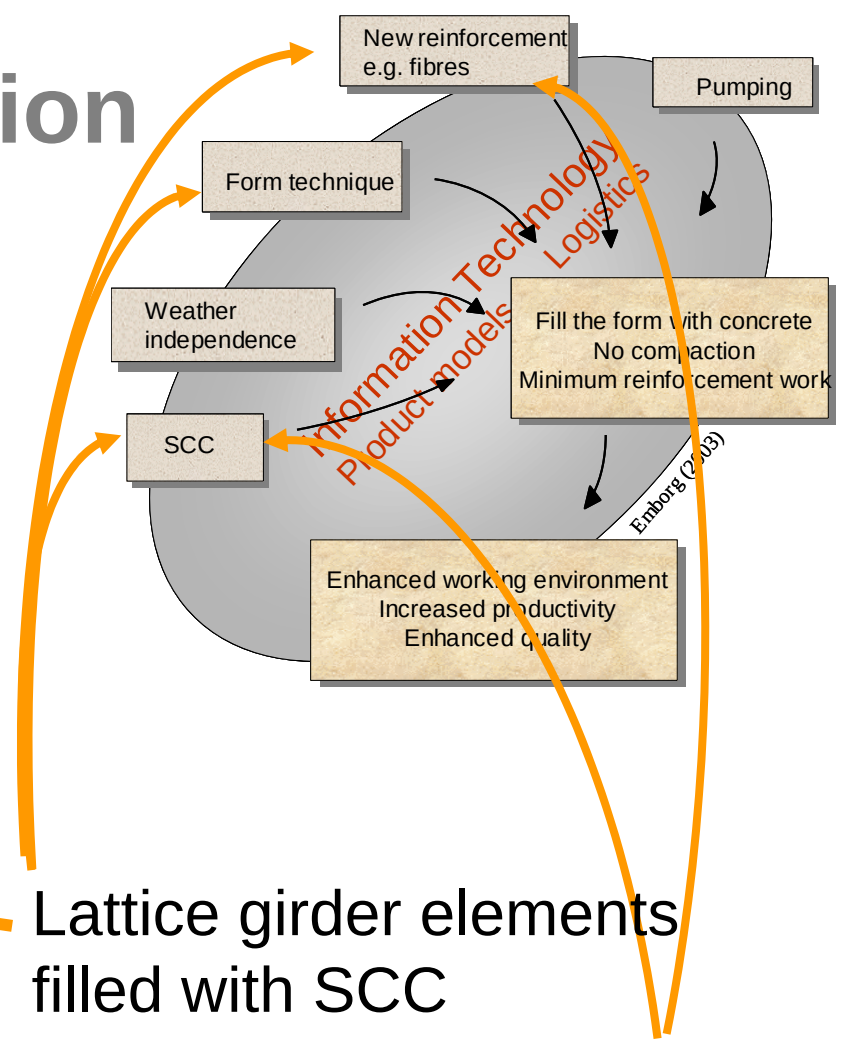
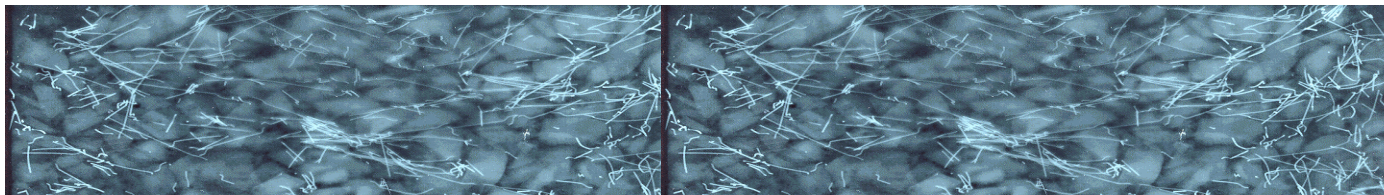
Industrial construction

- as many component as possible are combined



Lattice girder elements
filled with SCC

Steel fibre reinforced SCC
(X-ray examination)



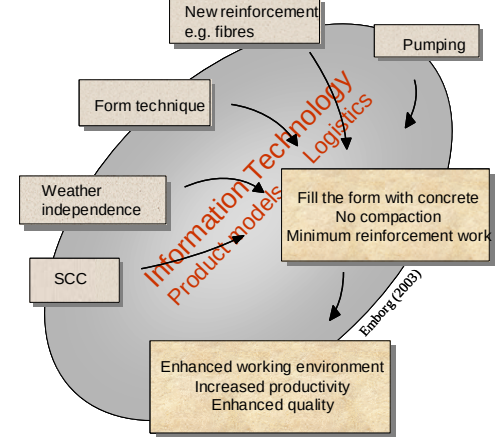
The future cast in place concrete....

- A highly industrialized process:

- Effective reinforcement fixing
- Rational form handling, left forms
- Weather independence



- **SCC** - accurately produced and executed





Disposition

- How to produce and transport SCC
 - Mats Emborg, Betongindustri, Luleå Univ Techn

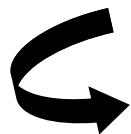
First SFR-SCC garage slab in N Europe

- Full Scale SCC Castings, DK
 - Lars Nyholm Thrane, Danish Technological Institute

First SCC wall – by the computer!

- Executions of Civil Engineering Structures
 - Thomas Österberg, Vägverket

First SCC bridge, Europe



Workshop sessions

PRODUCTION OF SCC

Mats Emborg

Betongindustri AB, Stockholm
Luleå University of Technology, Luleå



Betongindustri
HEIDELBERGCEMENT Group

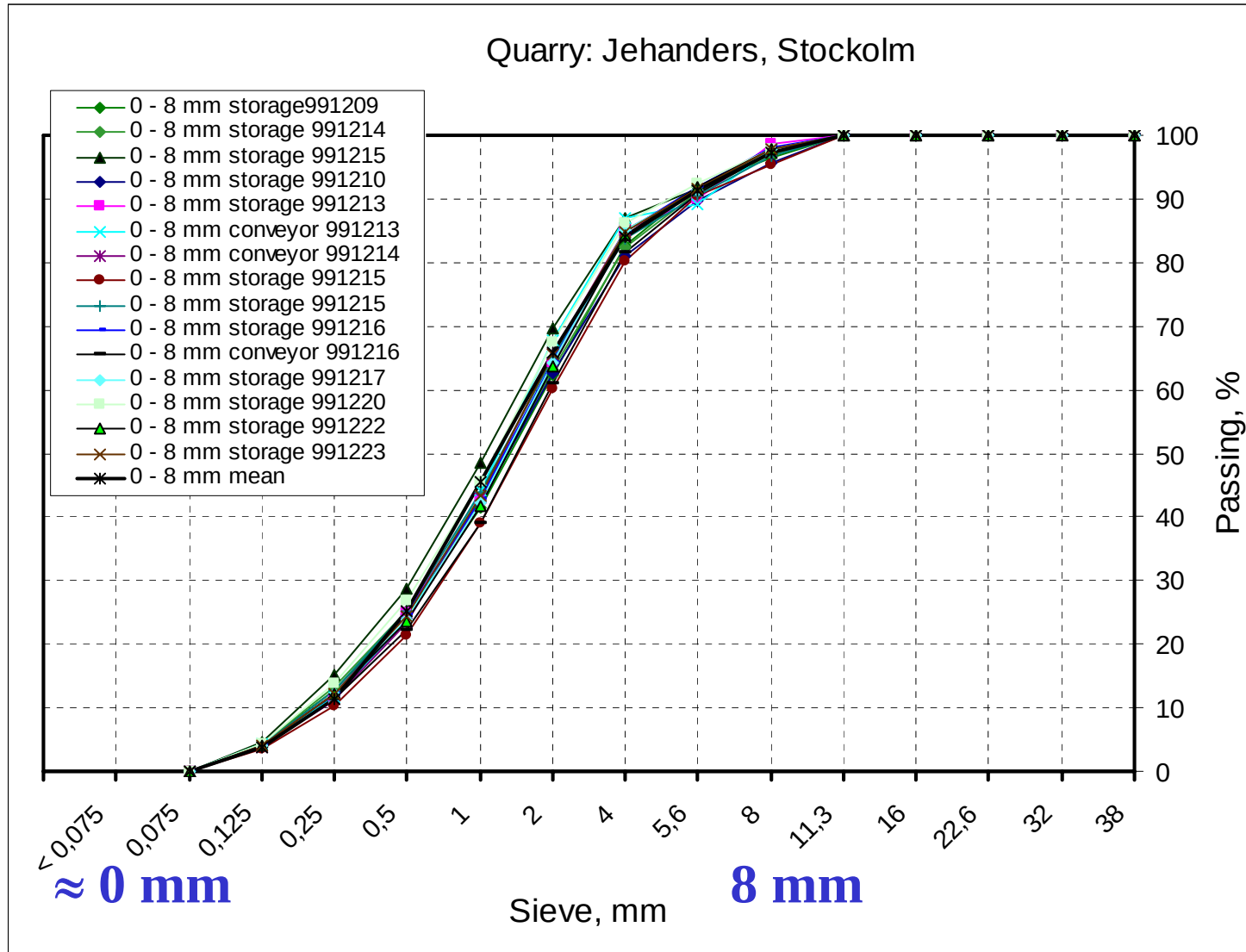
Content

- Concrete constituents
- Mixing
- Transport
- Delivery

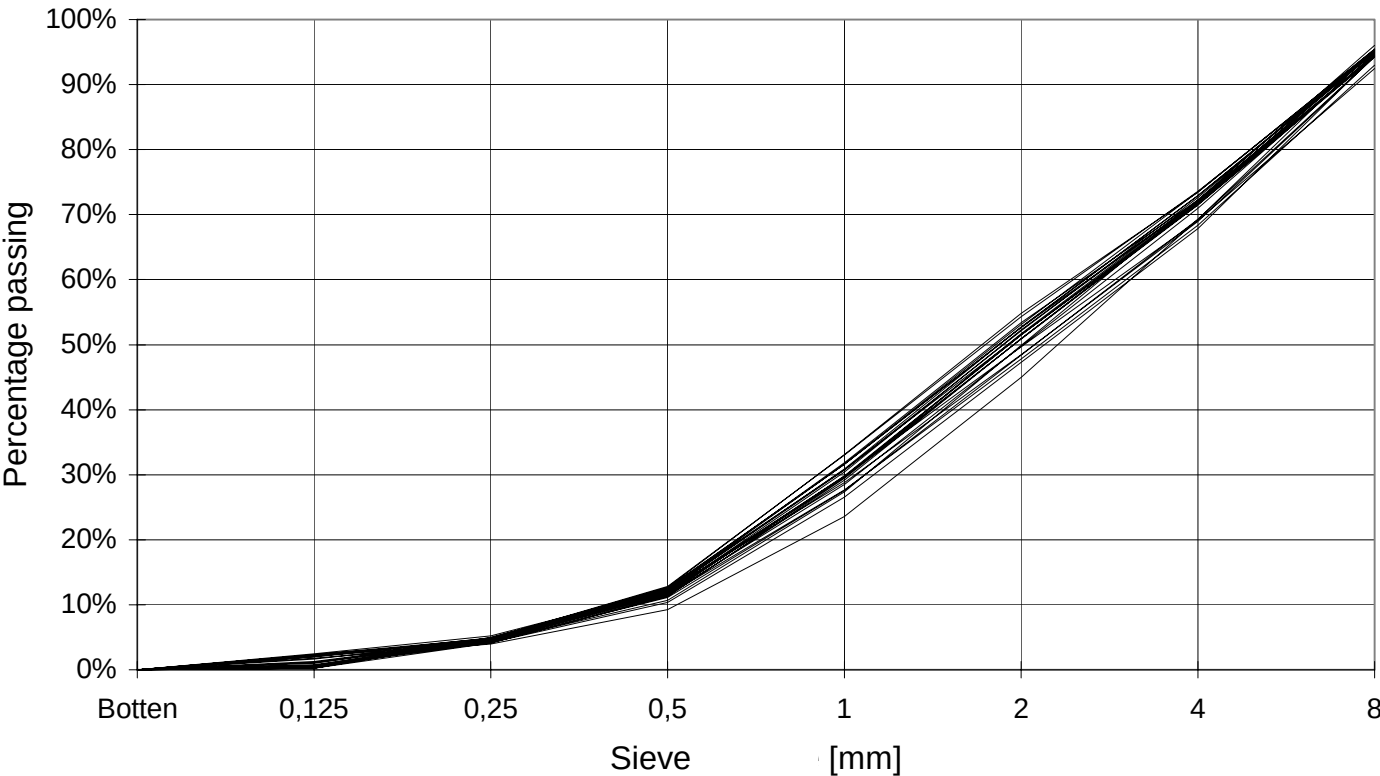


Variation of aggregate

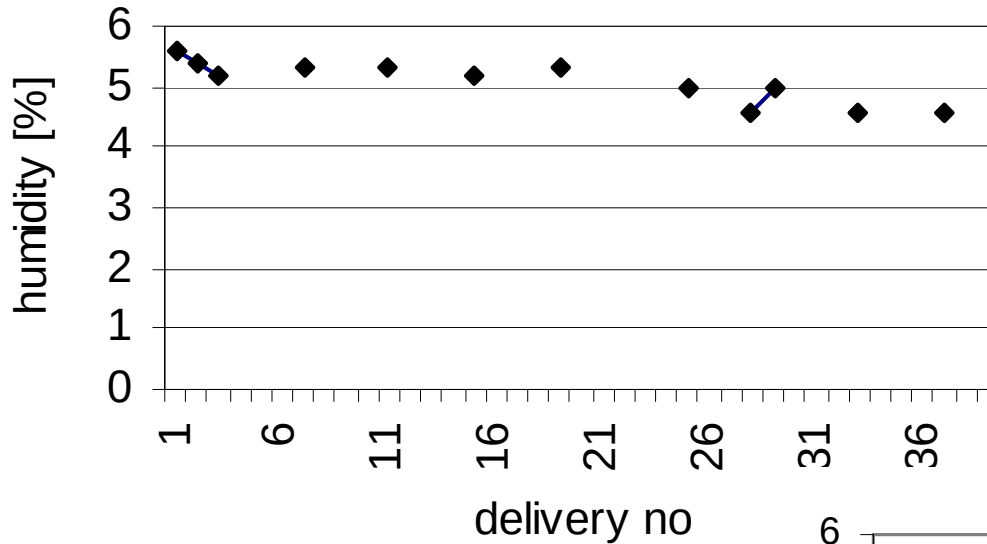
During
2 weeks



During
1 day

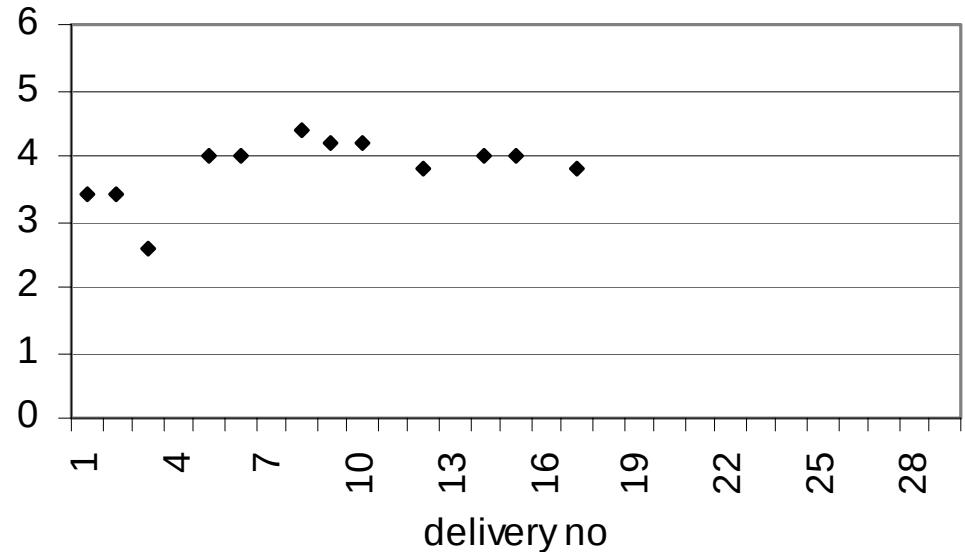


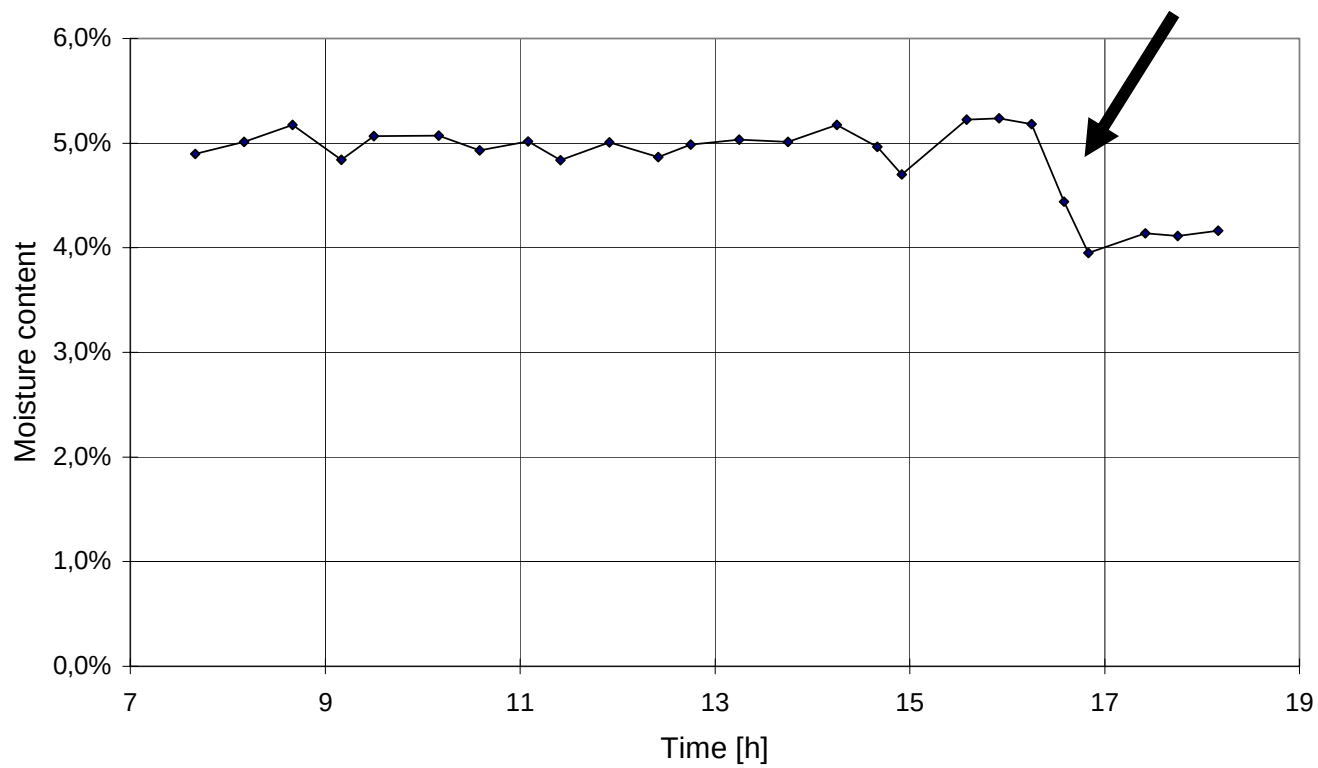
Variation of aggregate humidity



Delivery for
building site no 1

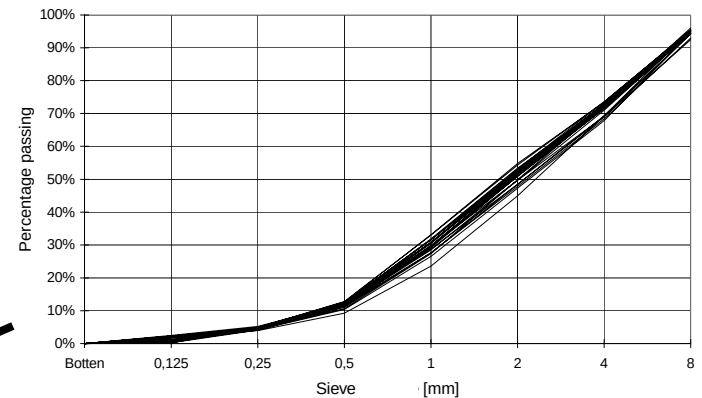
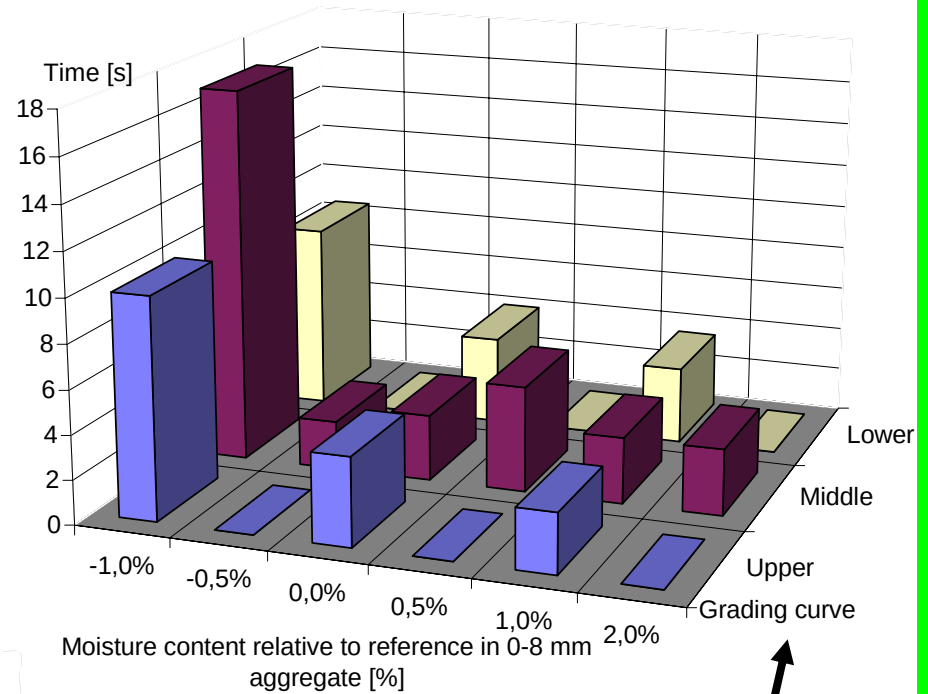
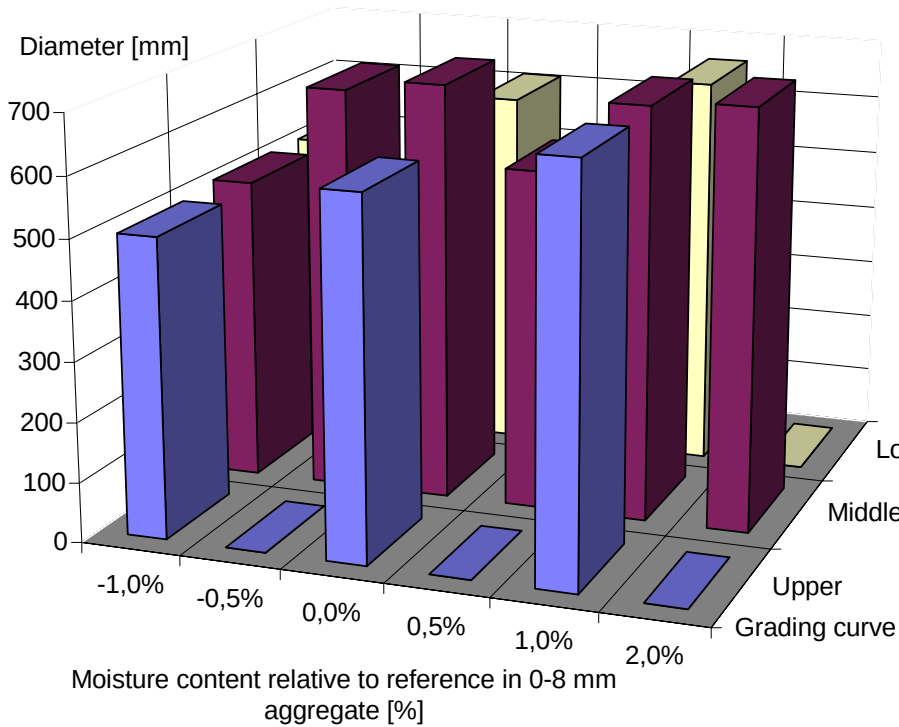
Delivery for
building site no 2



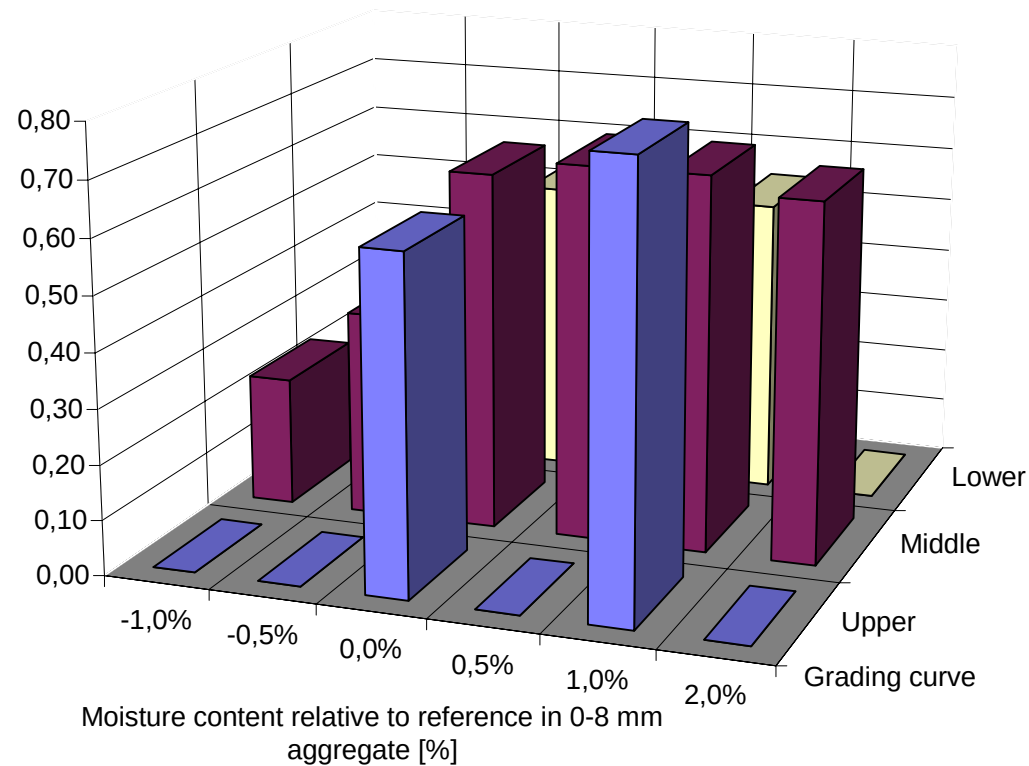


T50

Slumpflow



L-box



How much variations can we accept?

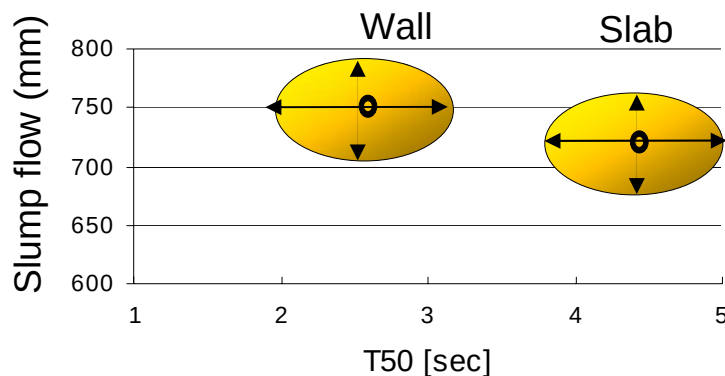
Criteria SCC

Example:

**Filling ability / flowability -
target value and tolerances**

**Depends on application
and casting method**

Workability:

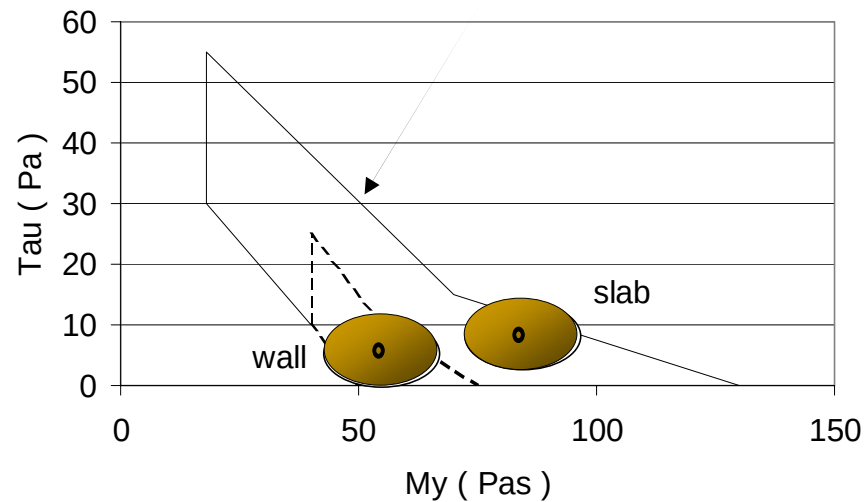


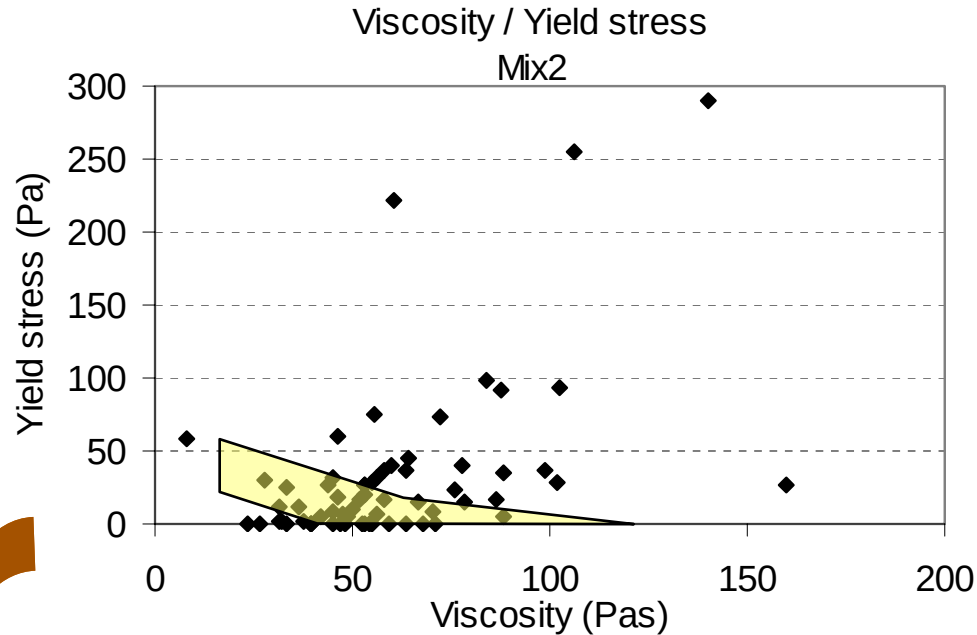
Accepted variations



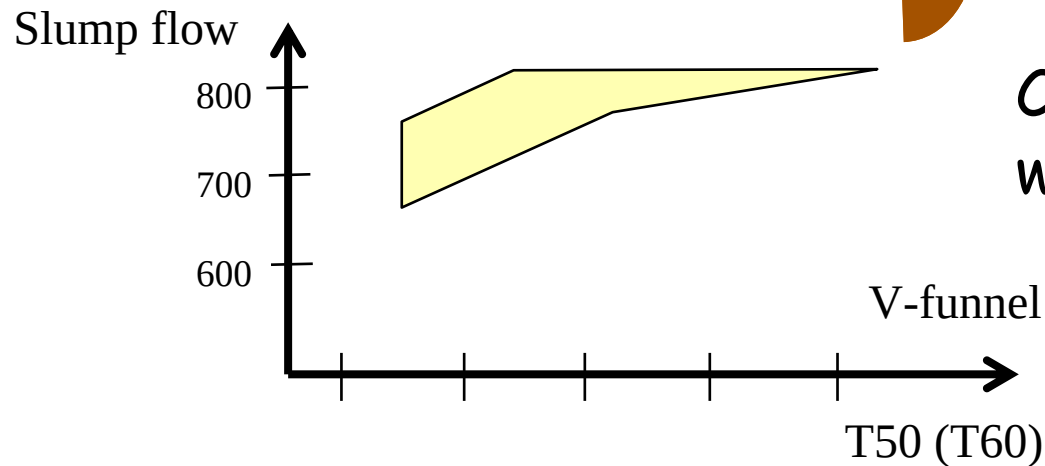
Rheology:

The "Wallevik area" for SCC

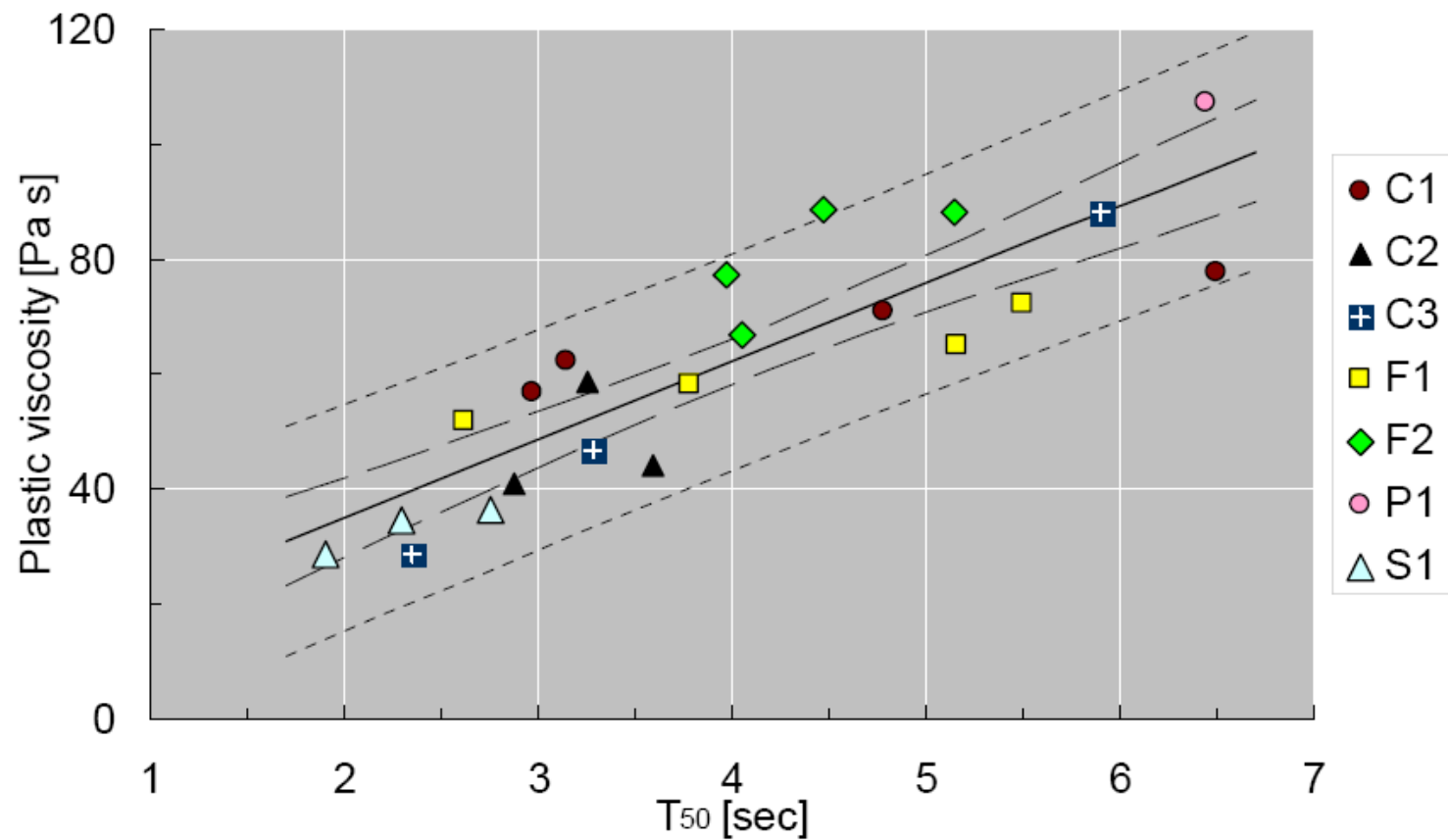




Example:
Target rheology area -
Concrete for housing



Corresponding
workability area



Criteria for SCC is
now suggested in:

Check them!

Input from
the European project
Testing – SCC
2001- 2004
(coord. Univ of Paisley
Scotland)



The European Guidelines
for
Self-Compacting Concrete
Specification, Production and Use



May 2005

SCC should fulfil the criteria

Robust SCC:

Admits variations of a number of factors:

- Fluctuations of properties of concrete constituents
- Mixing procedure
- Transport conditions
- Casting conditions
- etc

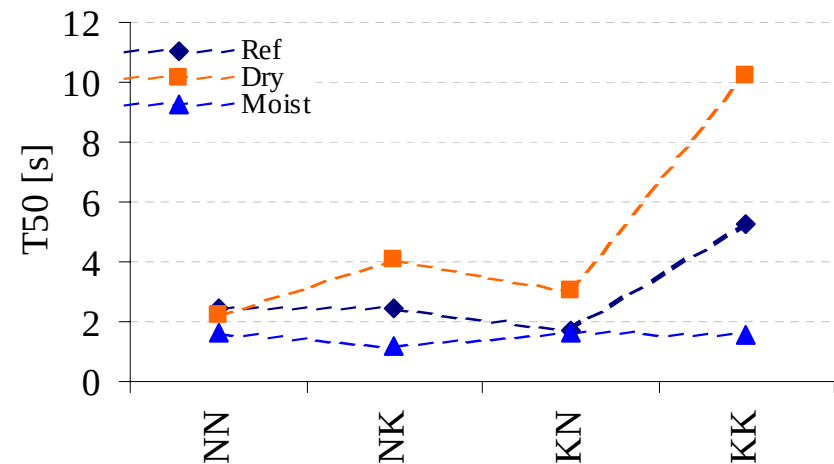
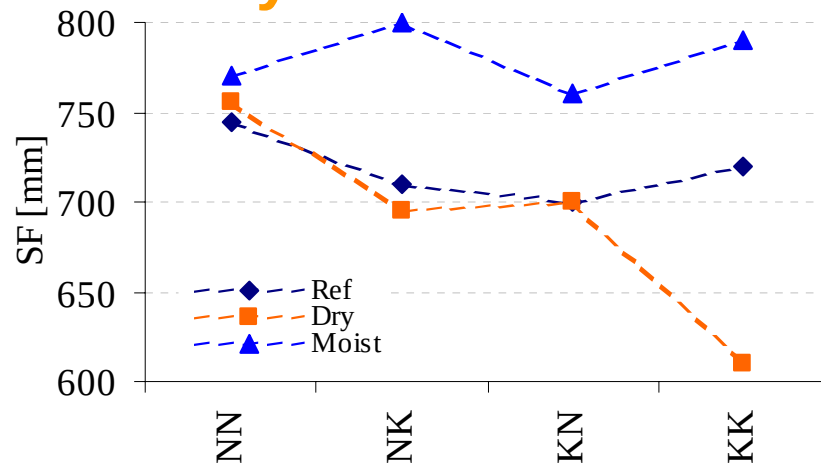
Project: influence of crushed aggregate



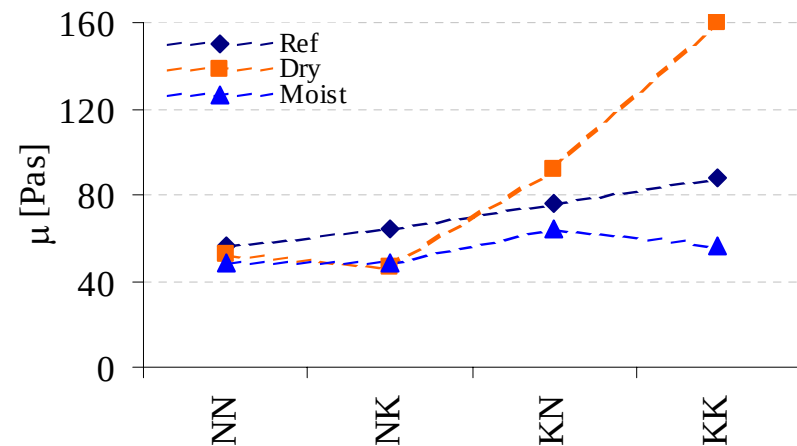
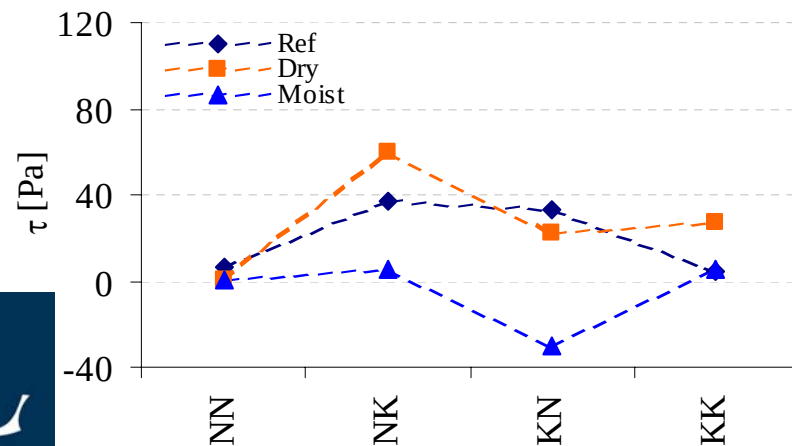
Robustness of SCC - example

Variation of water content - $\pm 0,5$ % of sand humidity
Natural (N), Crushed (K) aggregate, 0 – 8, 8 – 16 mm

Workability

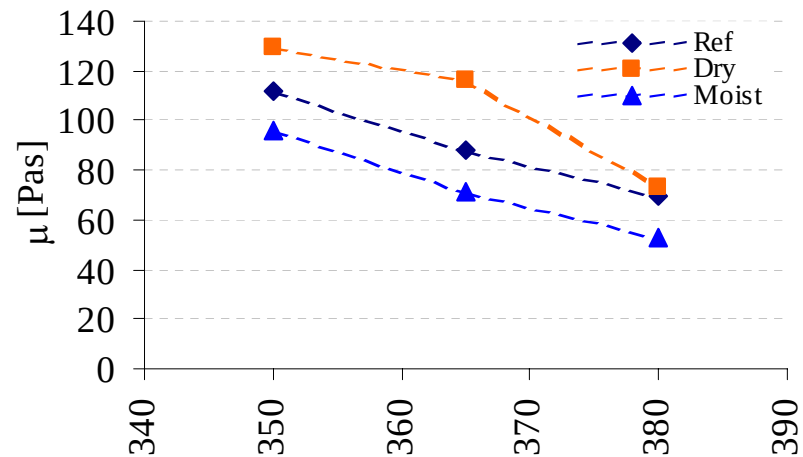
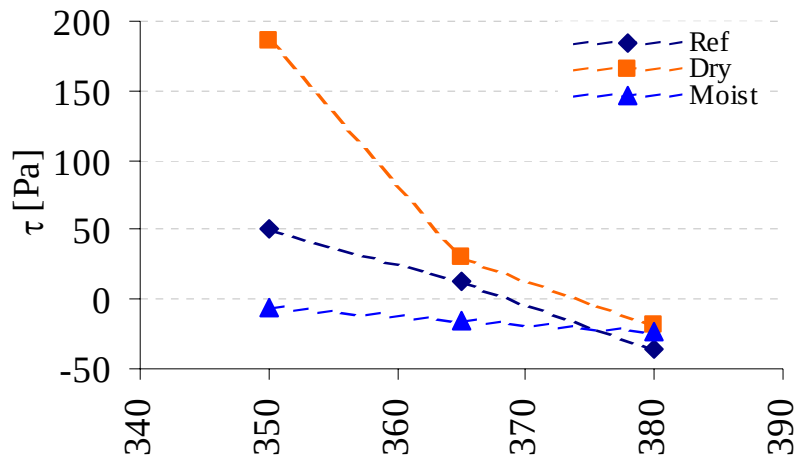


Rheology



Variation of water content - +/- 0,5 % of sand humidity
Crushed aggregate 0 – 16 mm
Increase of cement content

Rheology



Cement



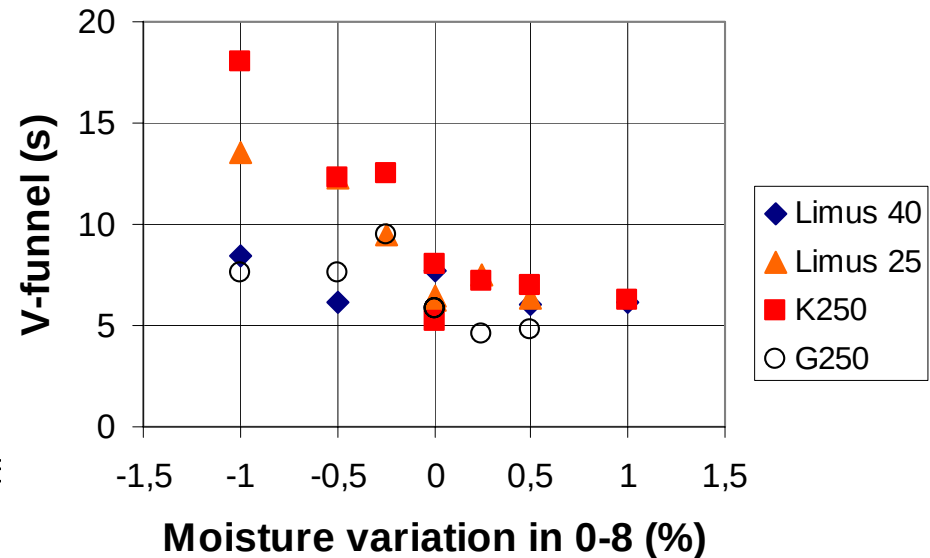
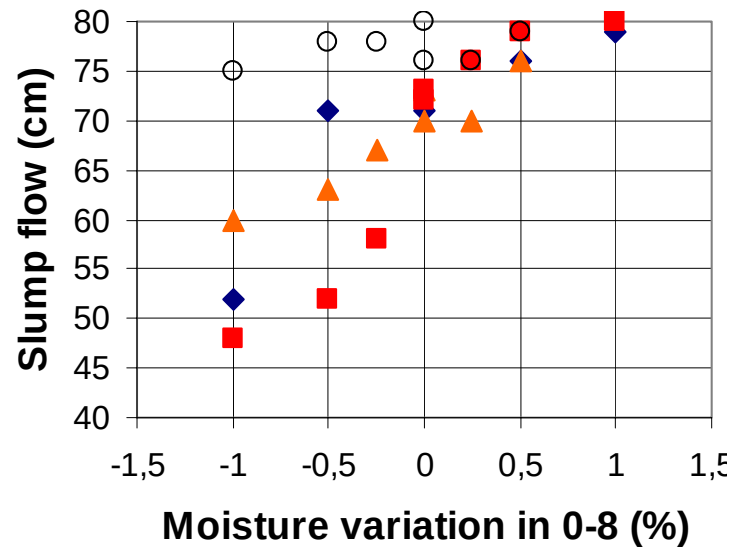
Betongindustri
HEIDELBERGCEMENT Group

Variation of water content - +/- 0.25, 0.5, 1 % of sand humidity

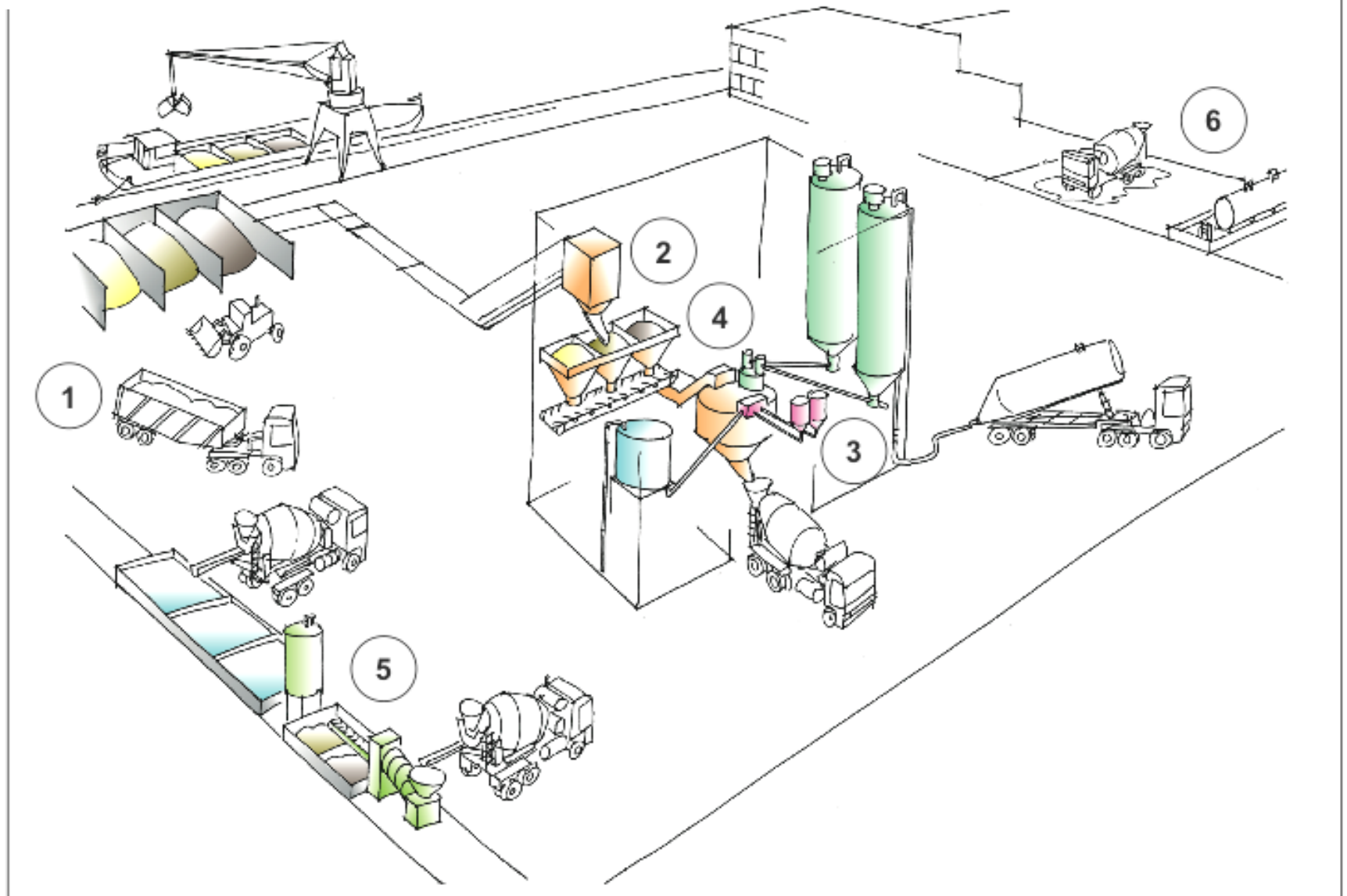
Natural aggregate

different filler

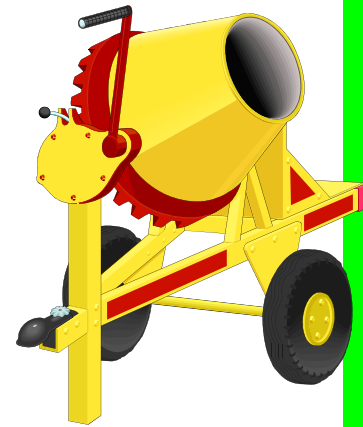
Workability



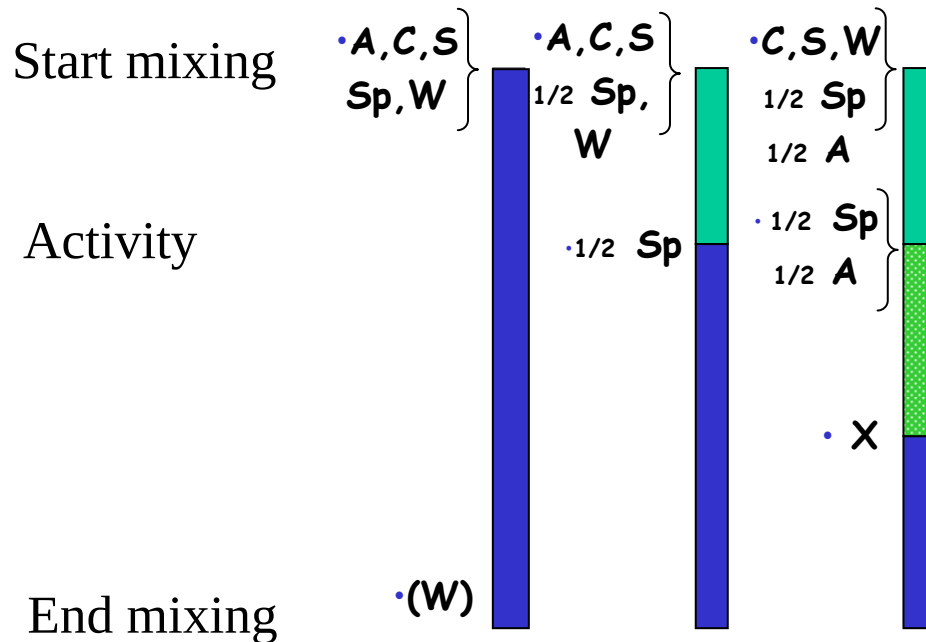
Mixing at the plant



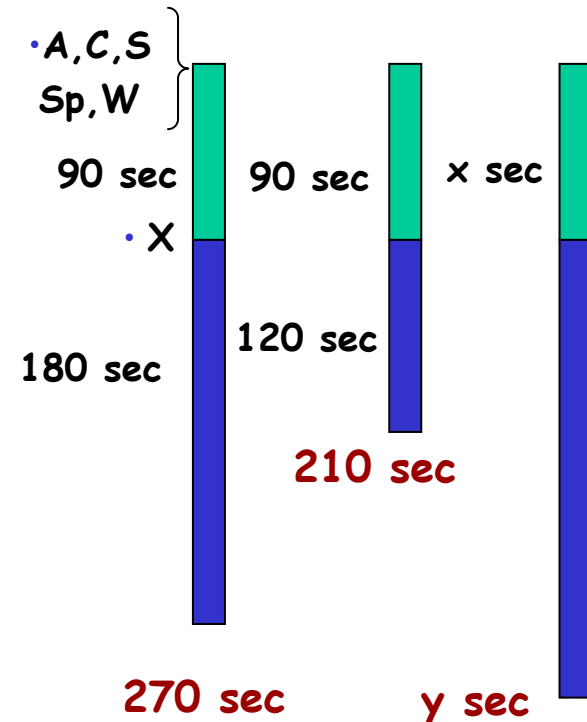
Mixing order, mixing time



Mixing order:

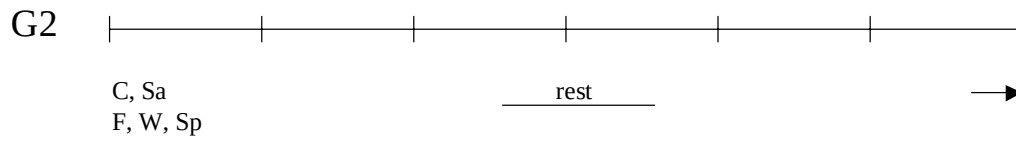
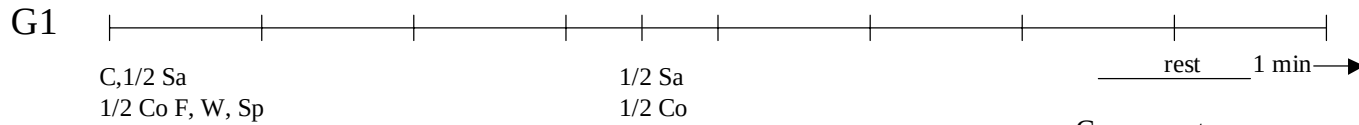
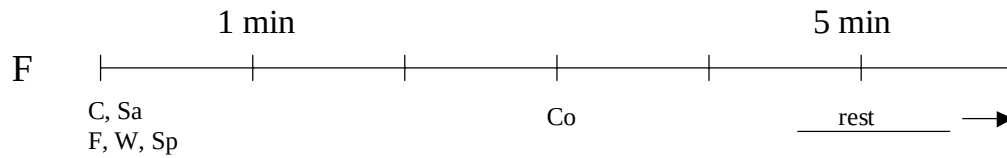


Mixing time:

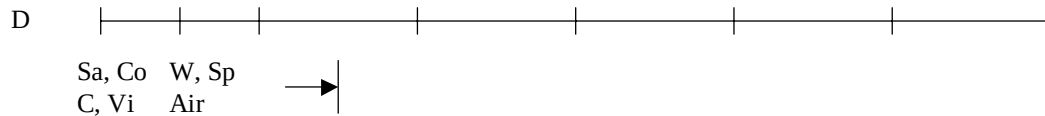
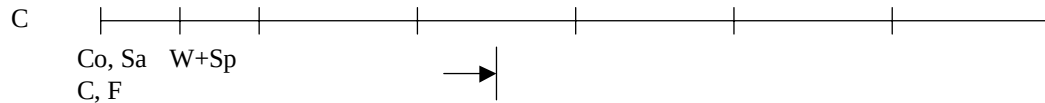
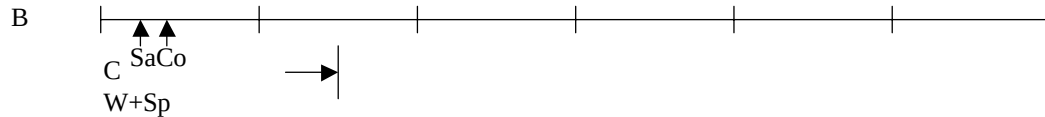
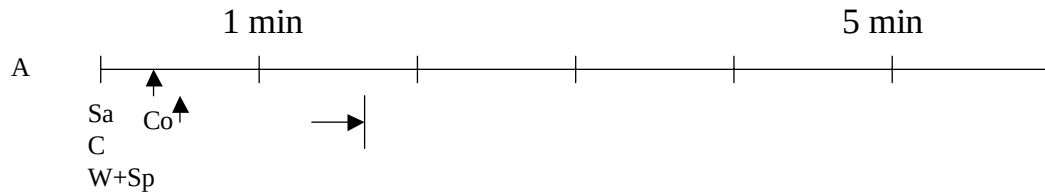


- **A** - aggregate, **C** - cement, **S** - filler,
- Sp** - superplasticiser, **W** - water

Mixing, examples

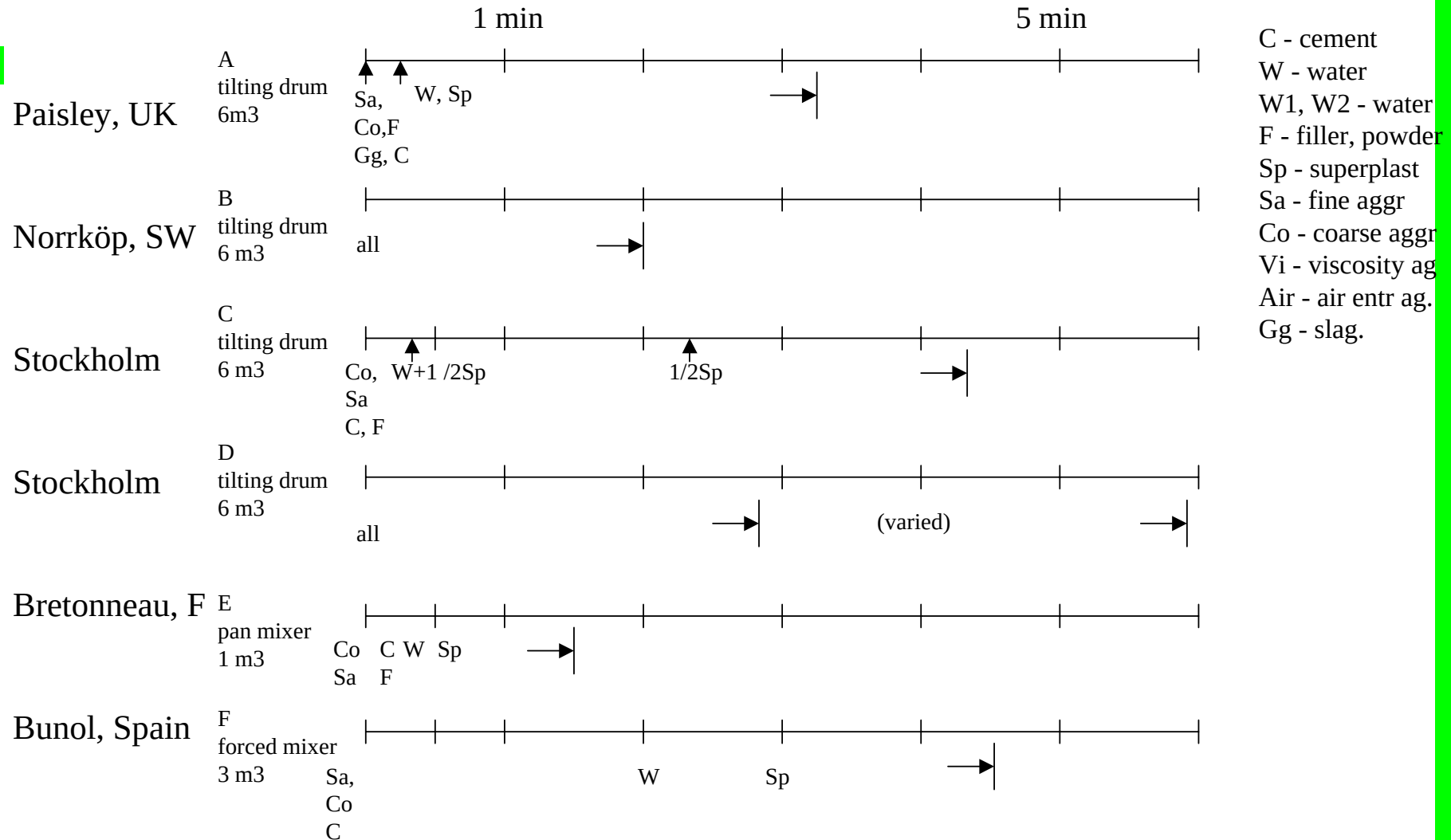


C - cement
W - water
F - filler, powder
A - aggregate
Sp - superplast
Sa - fine aggr
Co - coarse aggr
rest - resting



C - cement
W - water
W1, W2 - water
F - filler, powder
Sp - superplast
Sa - fine aggr
Co - coarse aggr
Vi - viscosity ag
Air - air entr ag..

Mixing, examples



Resis.

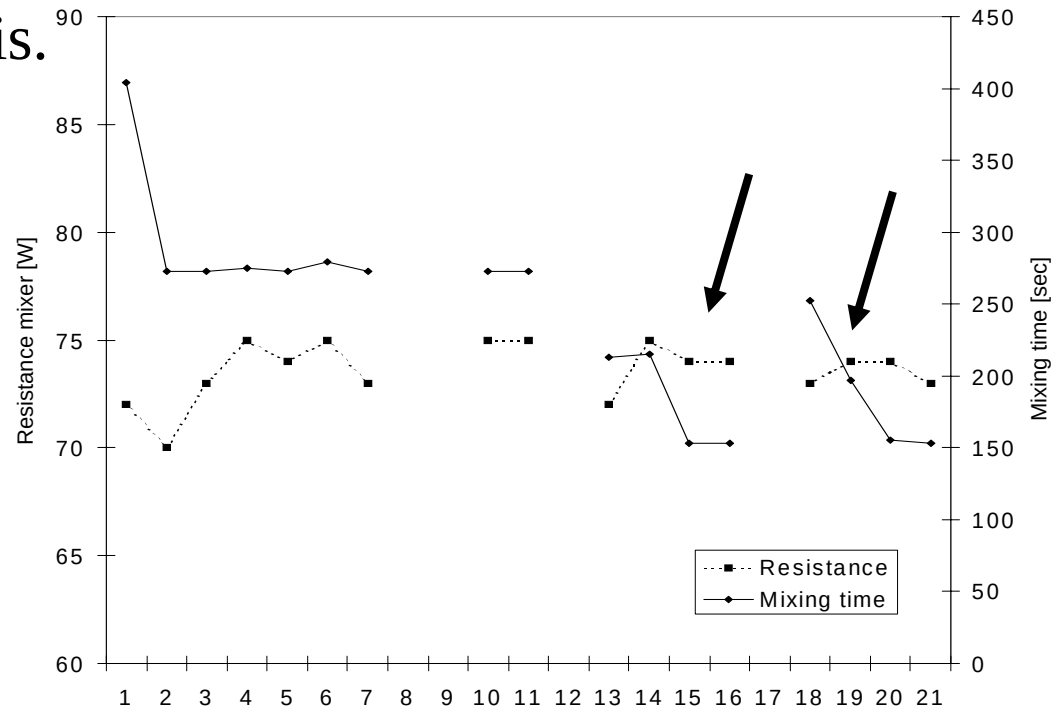
Time

Mixing time
Influence on
flowability

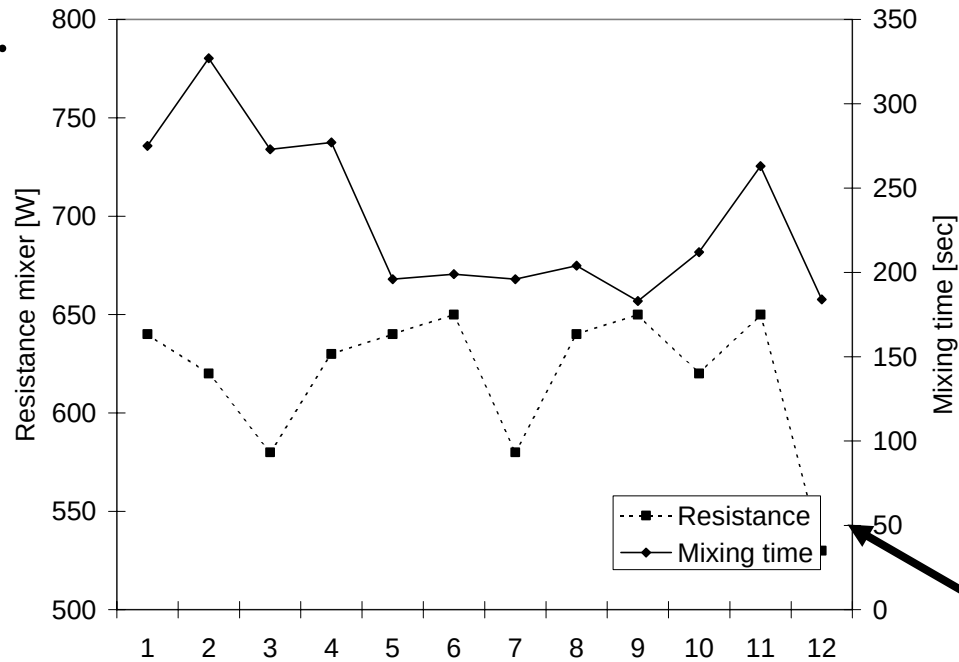
Mixer effect
and mixing time

Slump flow

Betongindustri
HEIDELBERGCEMENTGroup



Resis.



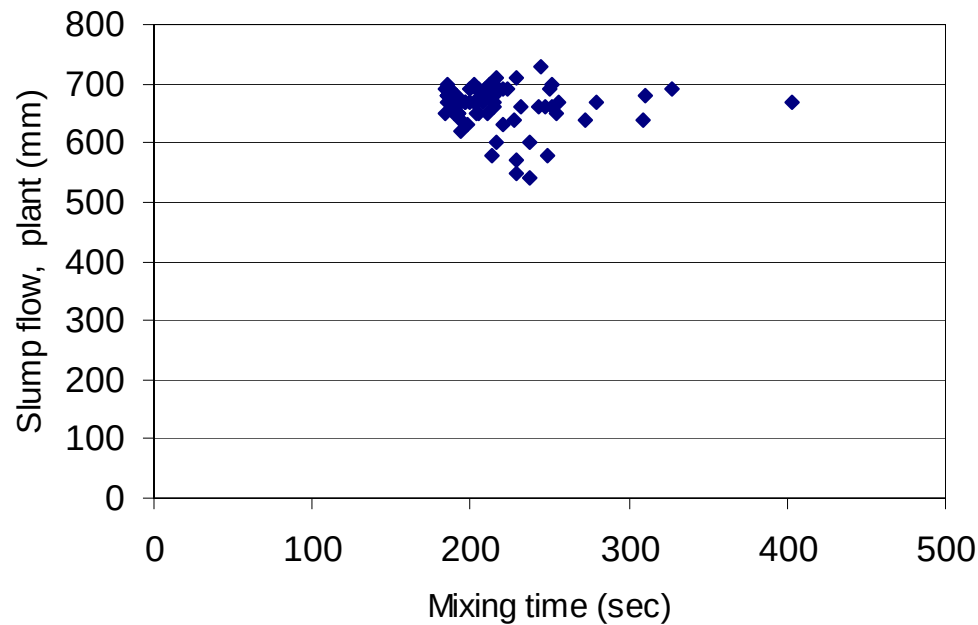
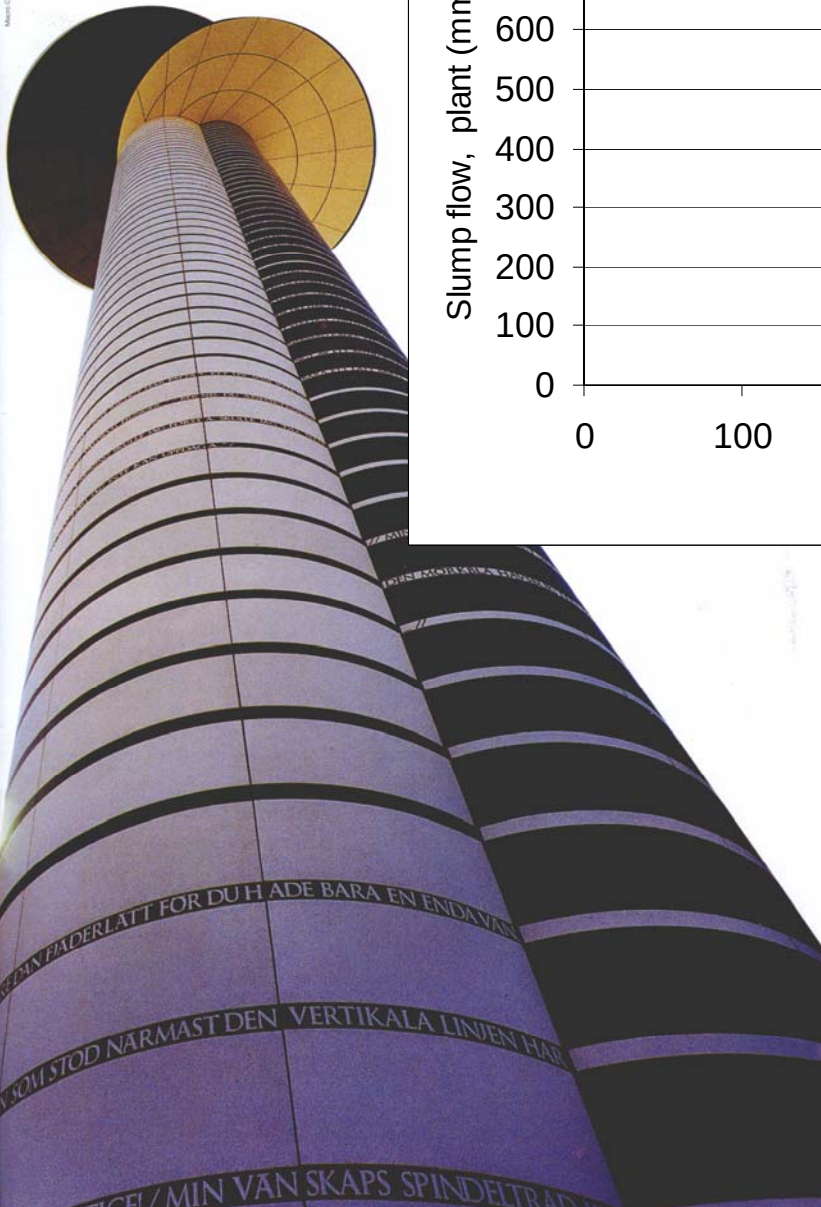
Time

Mixer effect
and mixing time



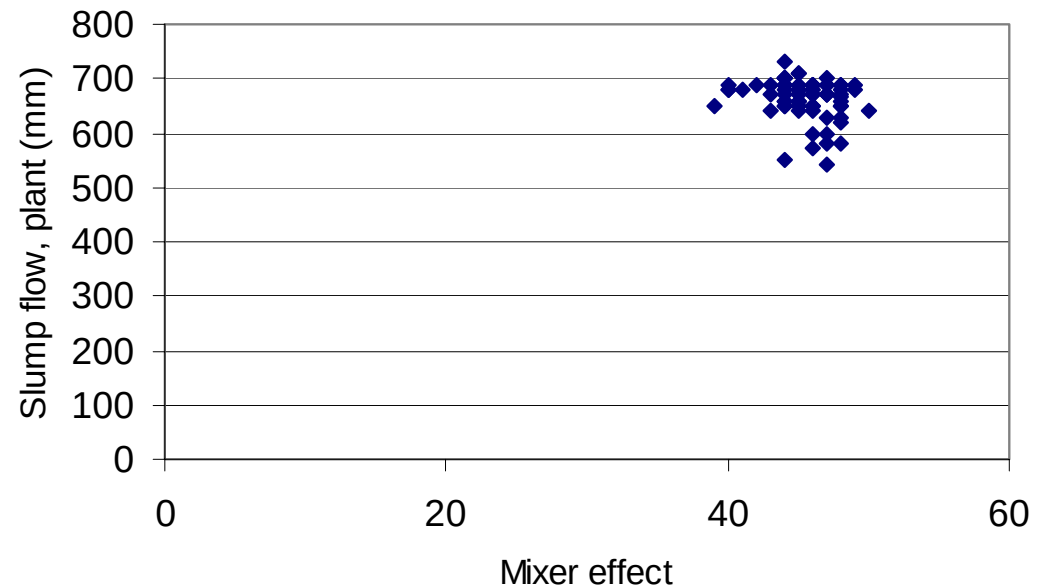
Slump flow

The Arlanda control tower



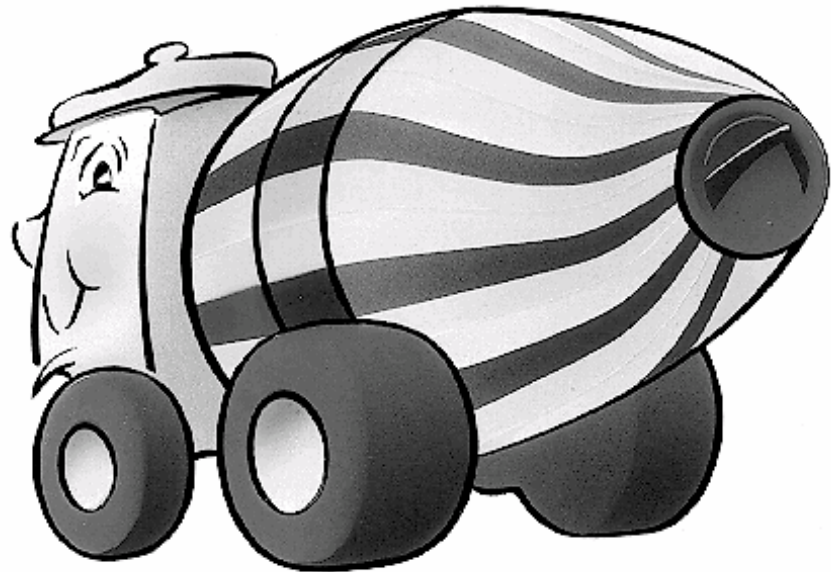
> 1000 m³
Transport:
5 – 10 min
Same mix

Here:
49 deliveries
(of 270)

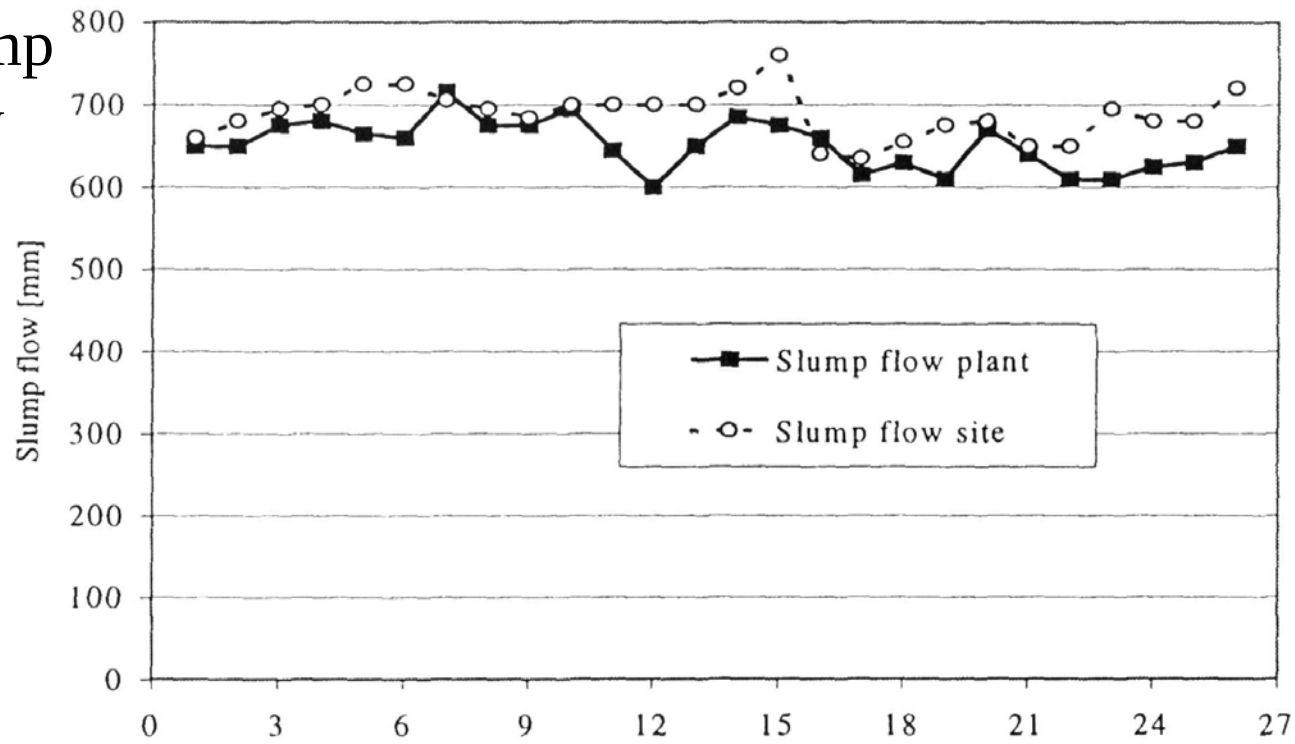


Transport

- influence of truck
 - type of drum
 - volume of drum
 - speed of revolution etc
- influence of length
 - temperature
- influence of concrete
 - superplasticiser



Slump
flow



Truck no



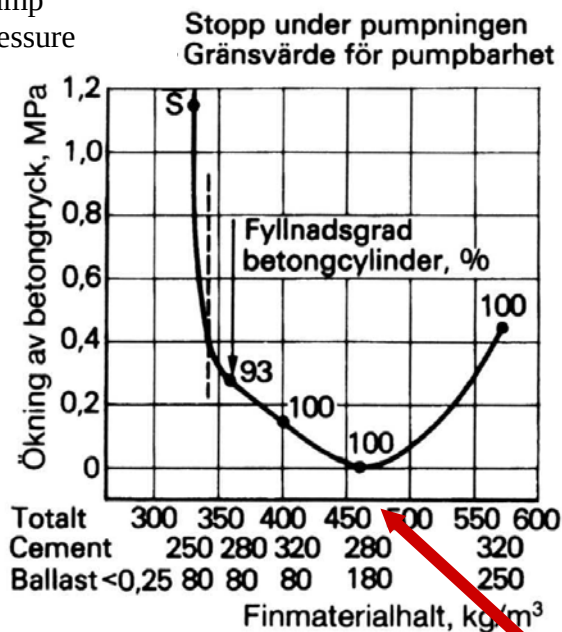
Pump

length, height,
pressure etc



Pump pressure

Pump
pressure



Cement + fines

SCC

Cement+ fines

Betongindustri
HEIDELBERGCEMENTGroup

Betongindustri, 2006

- Locally very large share of concrete production
 - 20 - 35 %
- Mainly housing concrete
- Prerequisites (conditions) at plants vary
- Limestone filler, crushed aggregate, superplasticiser
- Both larger contractors and smaller ones

Betongindustri, 2006

- Mixing order – all materials at once (some 10 sec between aggregate, cement, superplasticiser and water)
- Mixing times – not longer than for vibrated concrete
60 – 90 sec – concrete for housing,
90 – 120 (180) sec – civil eng concrete
- Careful check of resistance meter – mix, experienced based value for finalizing the mixing
- Diluting water at end often used – some 2 -3 l/m³
- Target plant SF-value depends on known effect of transport (increase or decrease of slump flow – concrete quality, superplasticies, filler etc and truck type)

Conclusions:

■ Production

- Production can be performed without any particular problems
- Standard type of mixing equipment can be used
- Higher degree of control at concrete plant is needed:
 - Include variation of material in mix design
 - Control of aggregate humidity variations
 - Mixing must be checked carefully prior to full scale production. (Mixing order, mixing time)



■ Transport/pumping

- Transport of SCC can be performed without any particular problems
- Normal types of trucks (with rotating drum) can be used. Transport time up to 1 h is possible
- Pumping of SCC can be performed without any particular problems with existing equipment
- Higher degree of site control is needed



Experiences from Vertical Full Scale Castings with SCC

Lars Nyholm Thrane

Danish Technological Institute, Concrete Centre

SCC Consortium

4K Beton A/S
MT Højgaard a/s
Aalborg Portland A/S
Videometer A/S
Betonelement a/s

Innovation Consortium partly
financed by the Ministry of Science
Technology and Innovation

Industri

DTU/IMM

Research

GTS Institutes

Danish Technological
Institute, Concrete Centre

Overall objective:

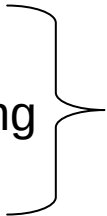
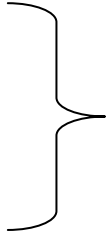
To improve the productivity and the working environment of the concrete industry

Outline

Introduction

Test setup

Results

- Form filling
 - Segregation/Blocking
 - Form pressure
- 
- Fresh state
-
- Surface finish
 - Frost resistance
 - Air void structure
- 
- Hardened state

Introduction

The use of SCC in vertical castings is still much lower than the use of SCC use in horizontal castings such as floors.

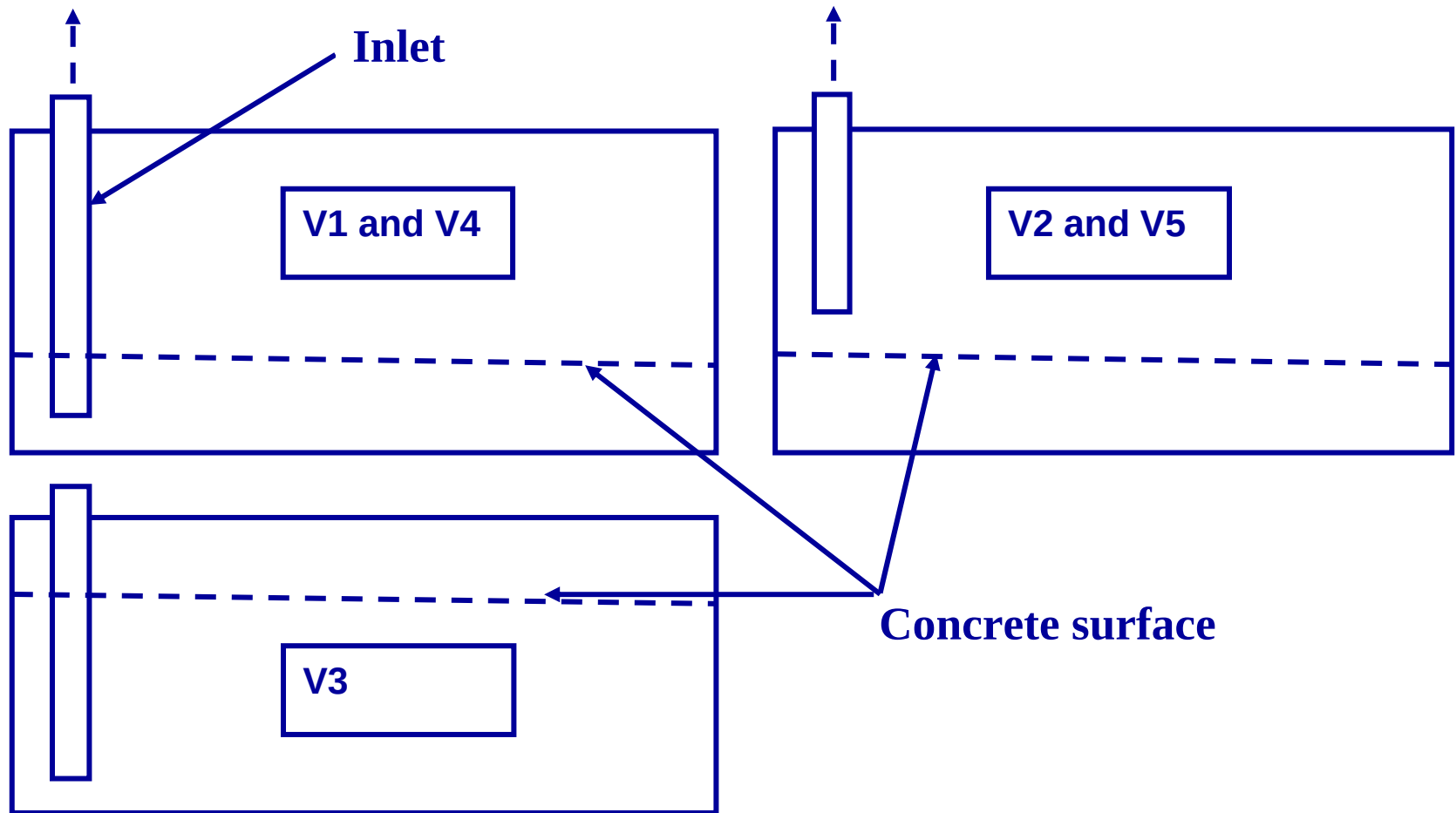
The aim of the full scale wall castings is to obtain experience on i.e.

- the relation between the fresh concrete workability, casting technique and the form filling behavior
- form pressure
- surface finish
- air void structure and frost resistance

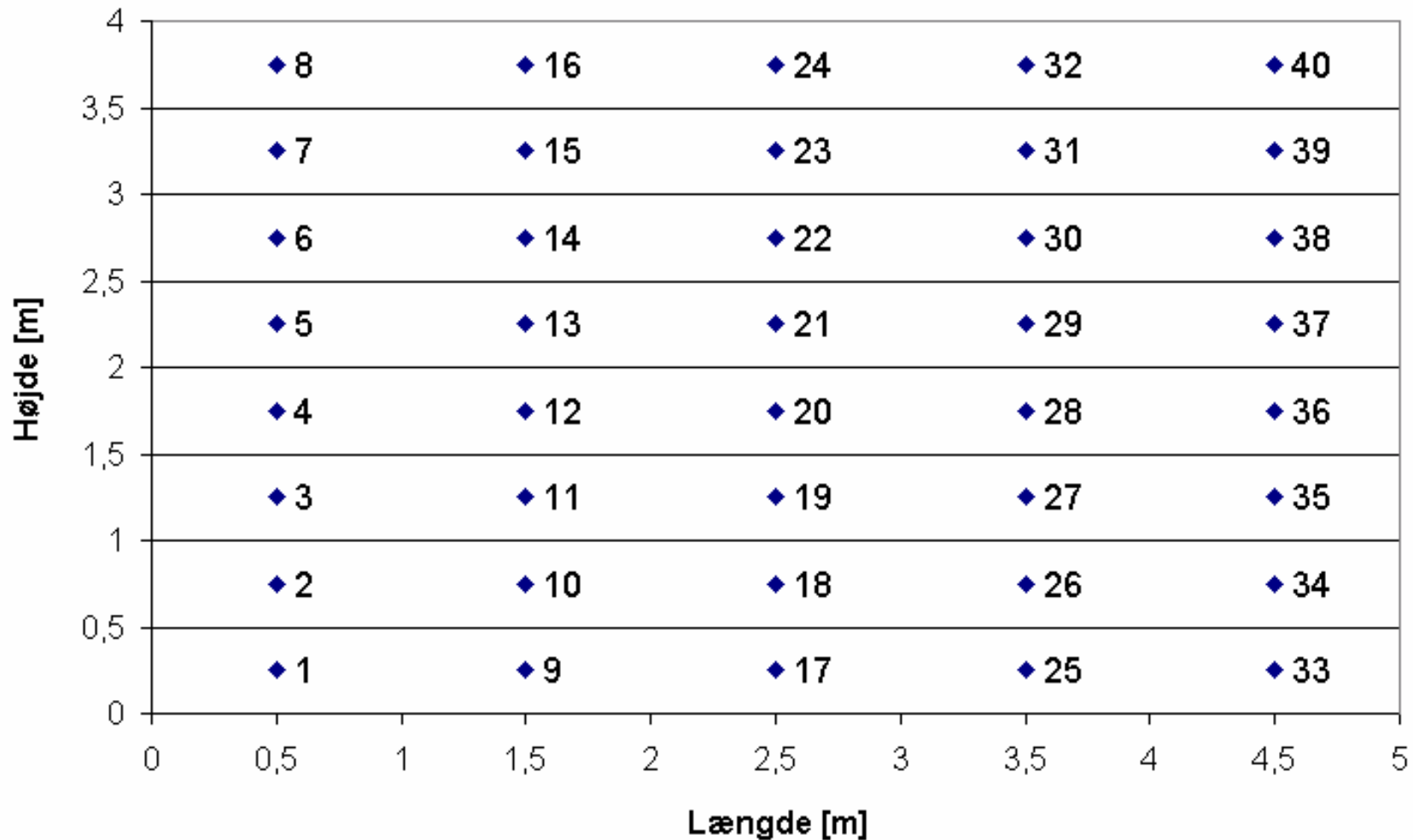
Test Setup

Wall ID	V1	V2	V3	V4	V5
Dimensions	$H * W * L = 4m * 0.5m * 5m$				
Concrete Type	A35	A35	A35	M30	M30

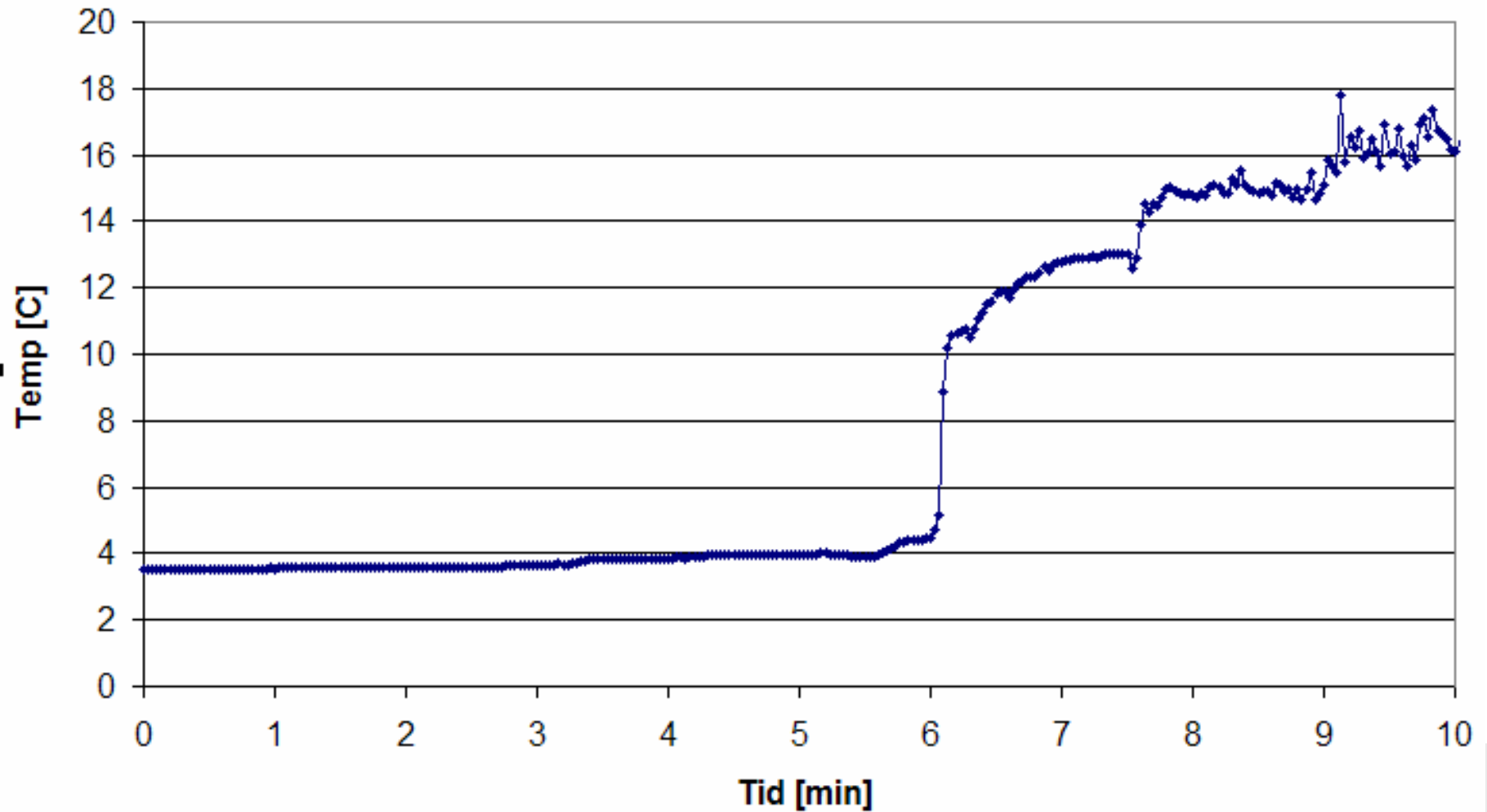
Test Setup



Test Setup



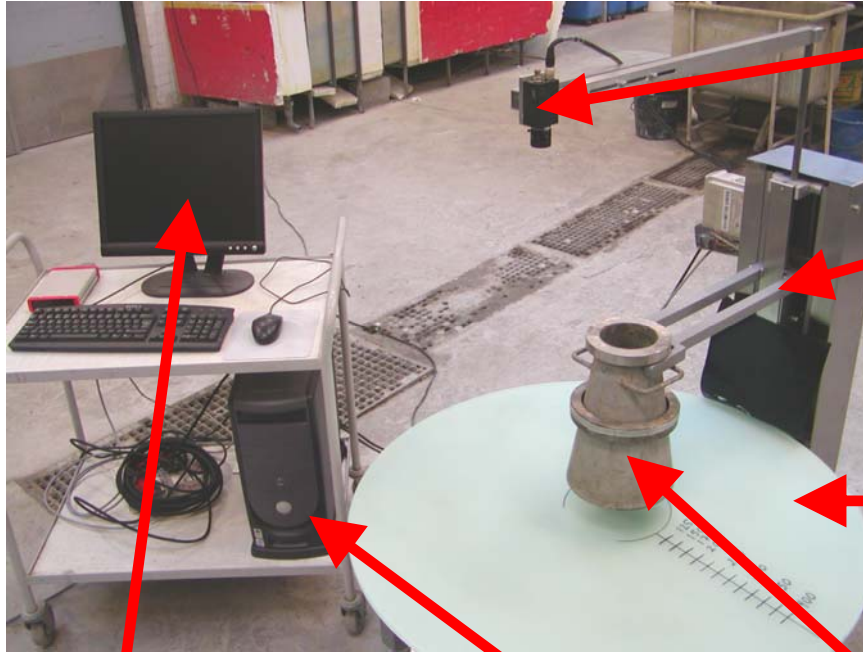
Test Setup



Test Setup

Slump Flow, Annex U i DS 2426	Compressive strength
Slump Flow, 4C Auto-slump	Heat development
J-ring	Finish
Air content	Macro analysis
Air void distribution: Air-Void-meter	Air void structure: EN 480-11
Form pressure	Frost Resistance: SS 13 72 44
Temperature	

4C Automatic Slump Flow



B/W Video camera

Lifting device – Ball screw ensures accurate lifting speed of 7 cm/s

Base plate in hardened sand blasted glass on adjustable rubber feet

Everything mounted on "rollers"

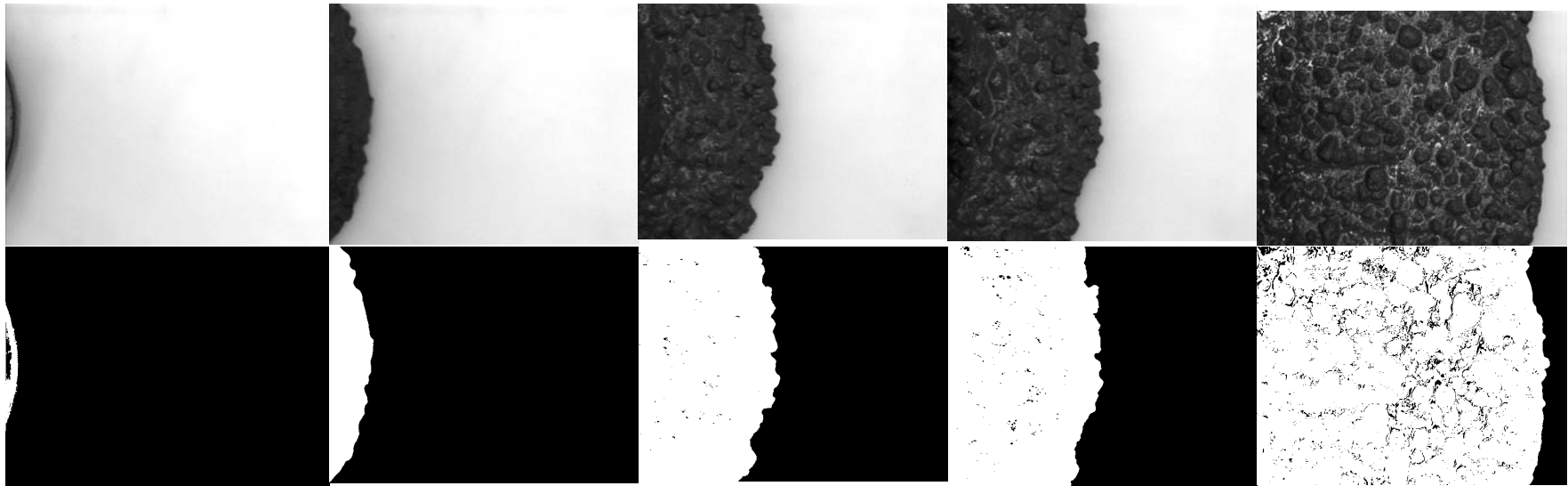
Monitor – one click and the analysis will proceed automatically

PC

Upright Abrams slump cone with weight ring

4C Automatic Slump Flow

Concept:



Raw image

Field of view 232 x 172mm – 640 x 480 pixels

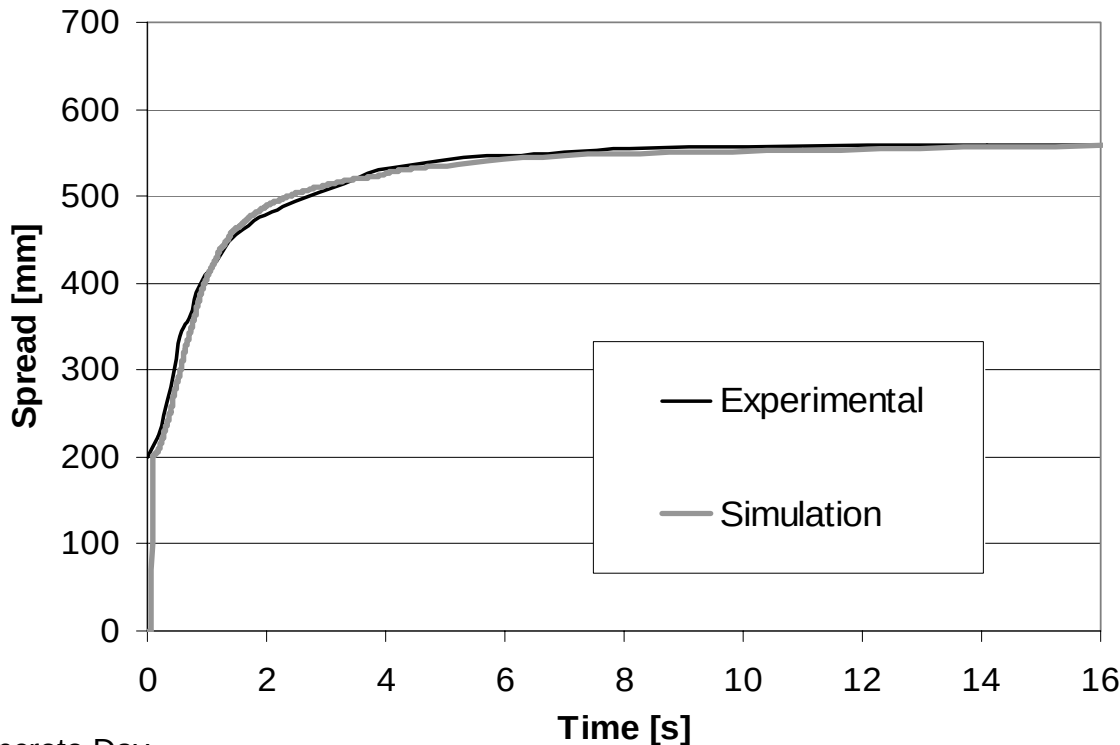
Spread as a function of time is determined –
30 images per second

Binary image –
only black and
white pixels

4C Automatic Slump Flow

Concept:

Raw image



Yield stress:

$$\tau_0 = 45 \text{ Pa}$$

Plastic viscosity:

$$\eta_{pl} = 30 \text{ Pa s}$$

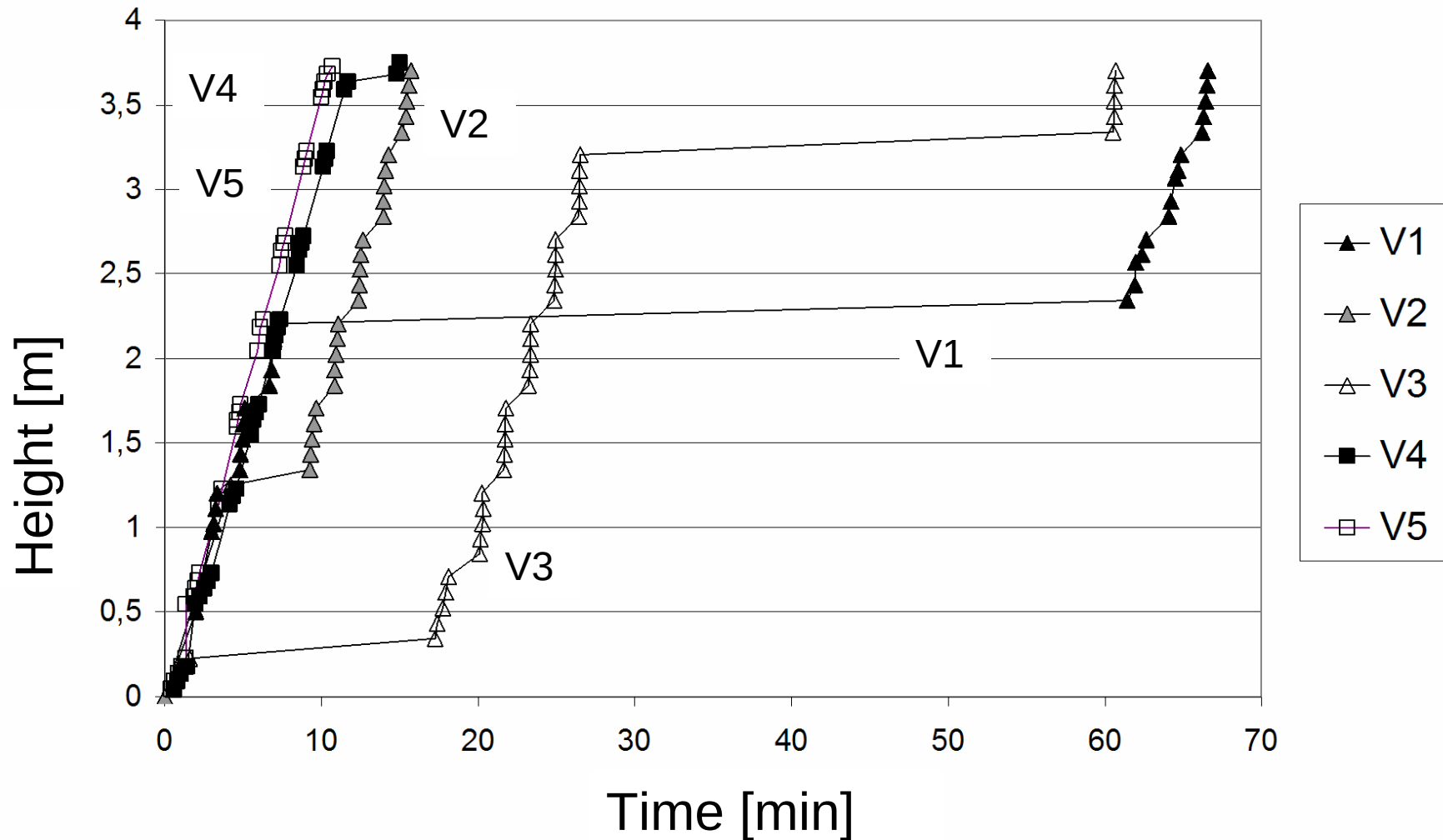
J-Ring



Results

	V1	V2	V3	V4	V5
Air [%]	5	6.6	5.1	8.5	7.1
SF [mm]	640	660	670	550	570
τ_0 [Pa]	20			60	45
η_{pl} [Pa·s]	60			34	34

Results

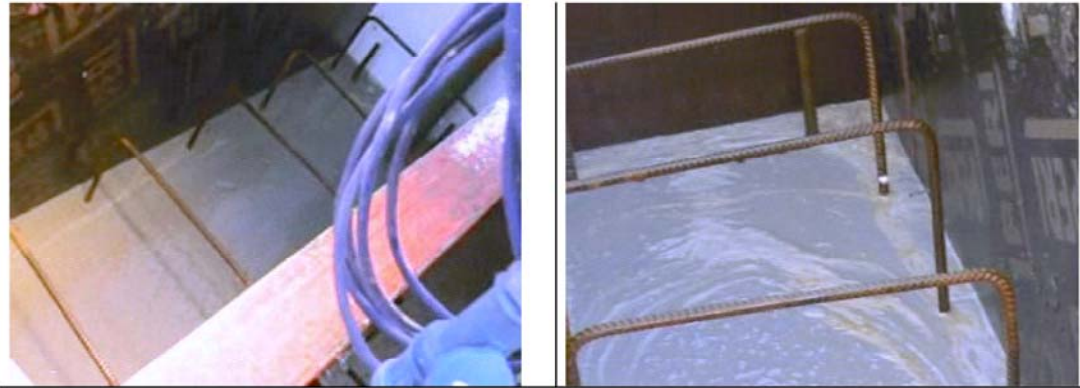


Results

Complete form filling was obtained. Depending on the rheological properties it was necessary to move the inlet to level the concrete surface.

Form geometry and reinforcement configuration do not prevent high casting rates of up to 25 m/hour. However, may have to lower due to e.g. finish and form pressure.

Results

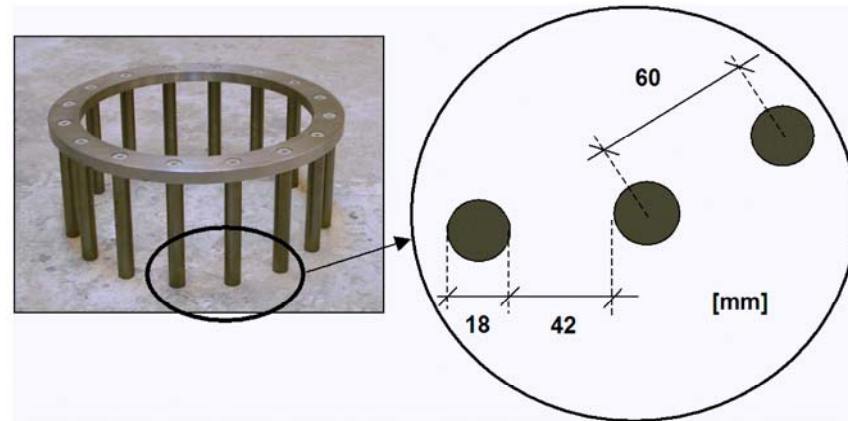


V1(~ 2 cm)



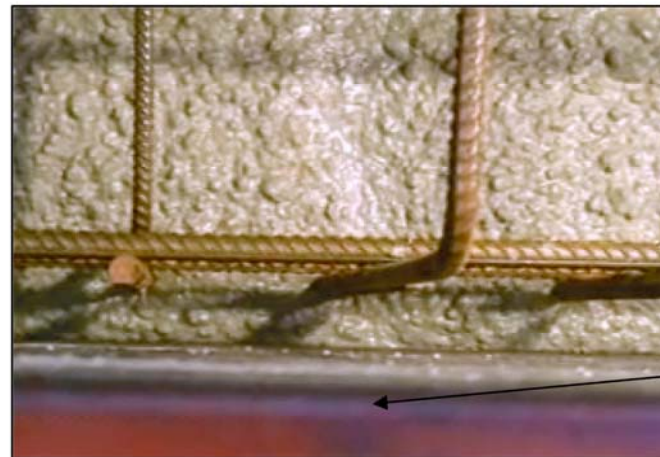
V4 (~ 10 cm)

Results



2.6

Blocking was not observed during form filling.



3.2

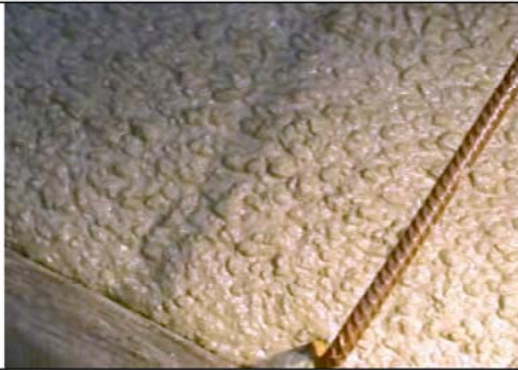
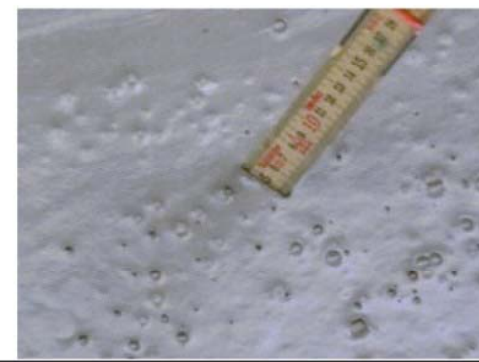
Res



V4 (0 cm)



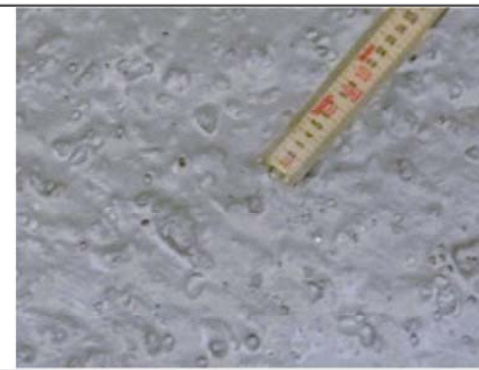
V1 (~ 5 cm)



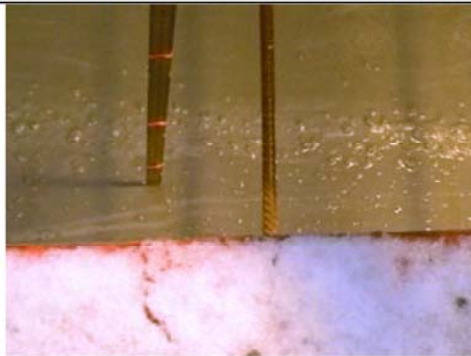
V5 (0 cm)



V2 (~ 0 cm)



Dynamic segretion very dependent on the casting technique and the rheological properties.



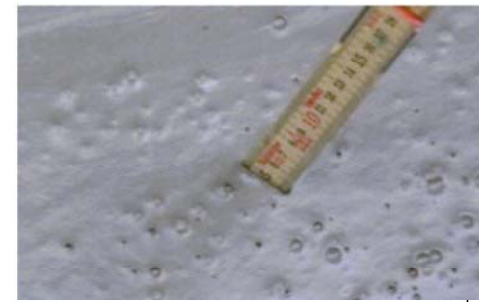
V3 (~ 10 cm)



Res



V4 (0 cm)



V5 (0 cm)

Dynamic segretion very dependent on the casting technique and the rheological properties.

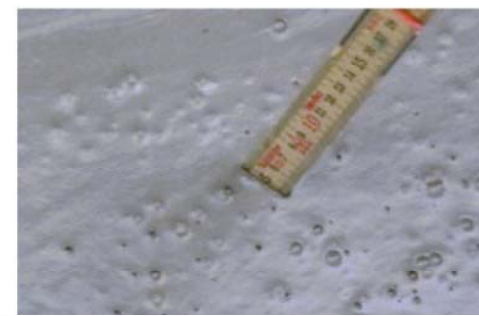


V3 (~ 10 cm)

Res

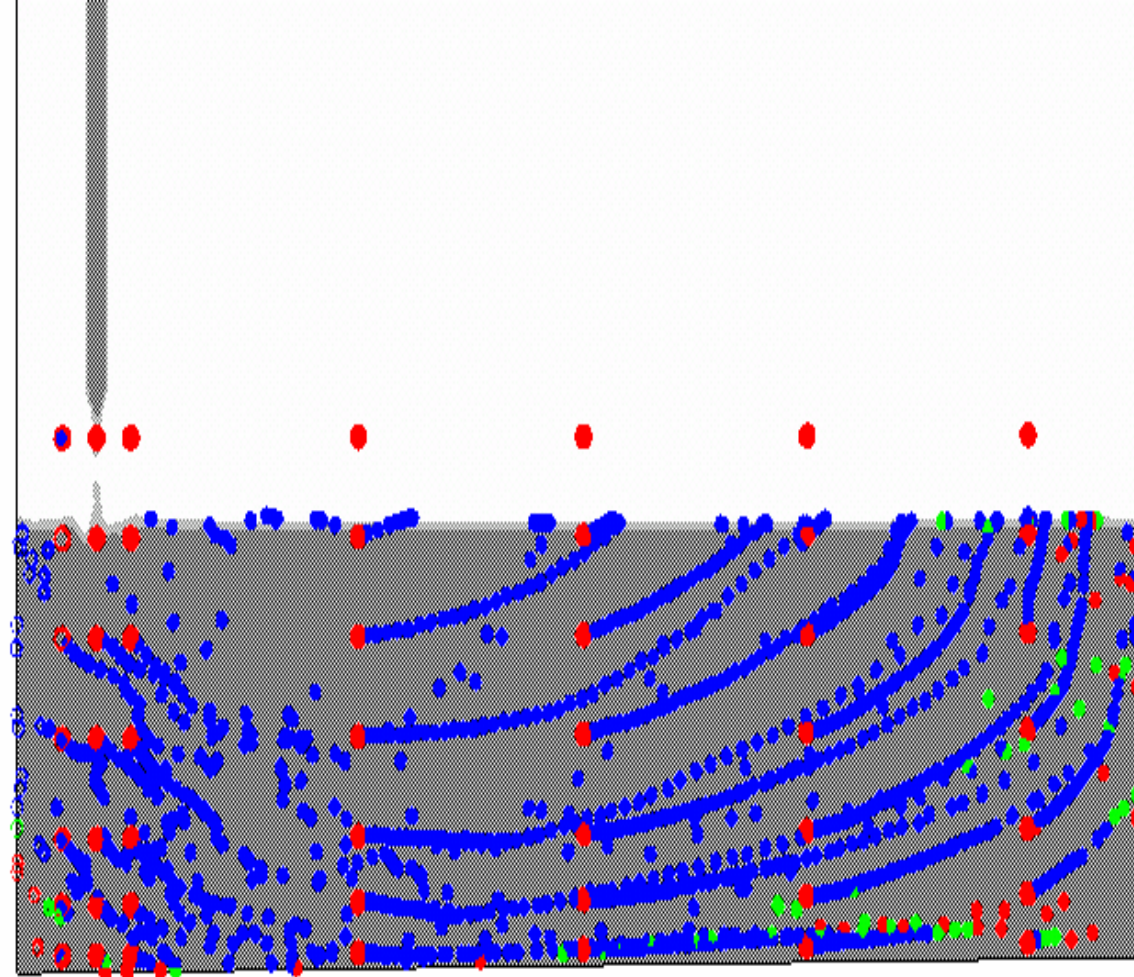


V4 (0 cm)



V5 (0 cm)

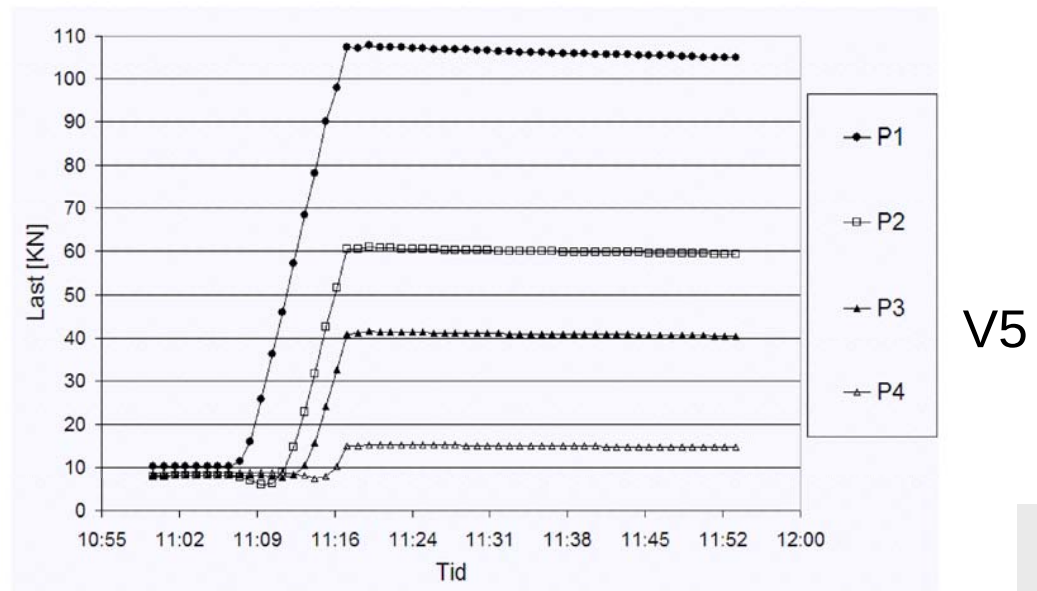
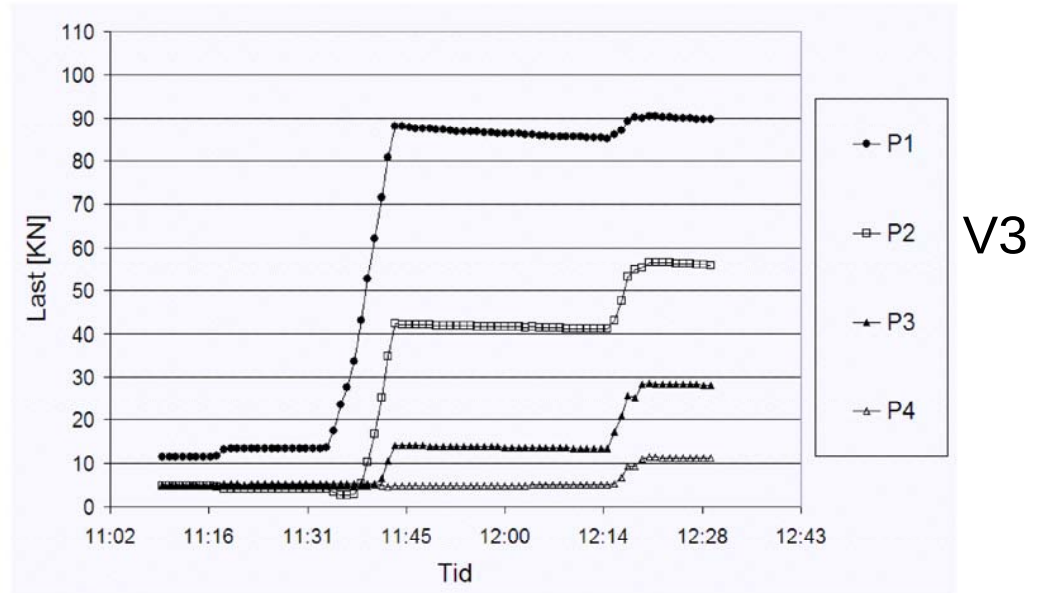
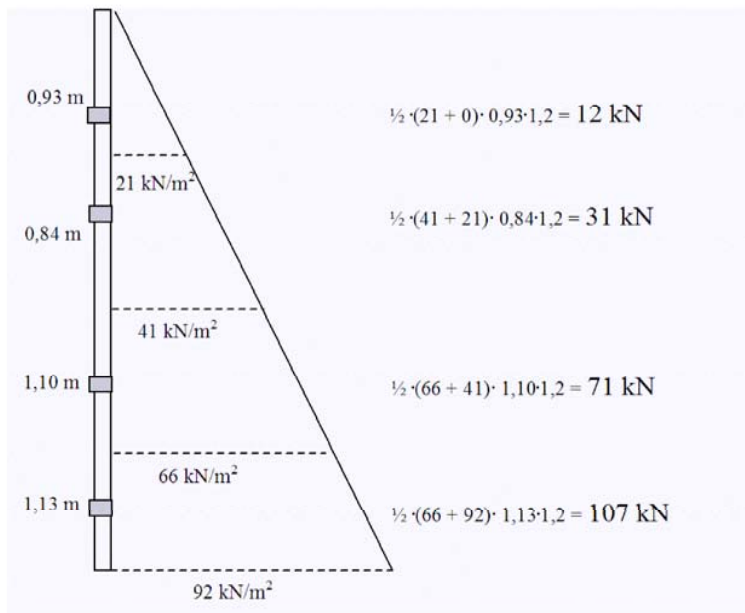
Dynamic segregation very dependent on the casting technique and the rheological properties.



V3 (~ 10 cm)

Results

Hydrostatic pressure is obtained (> 18 m/hour)



Results

2 types of form oil:

- Bricon Unislip 9-12, mineral oil
- Emulfix LL, vegetable formolie

Visual inspection showed no difference in surface finish.

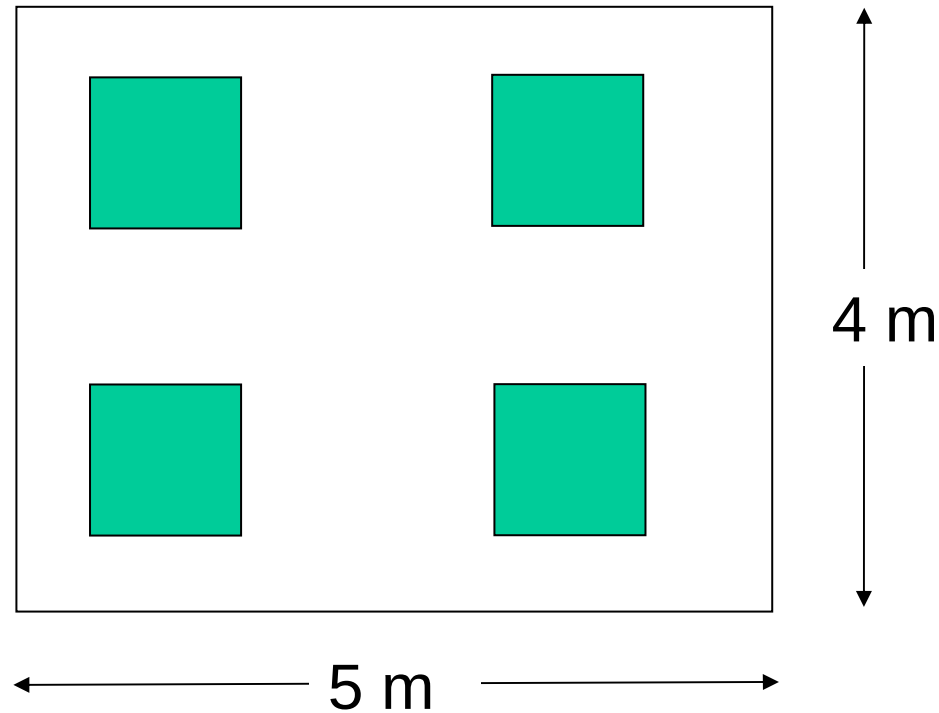
Results

Finish is evaluated by counting pores according to:

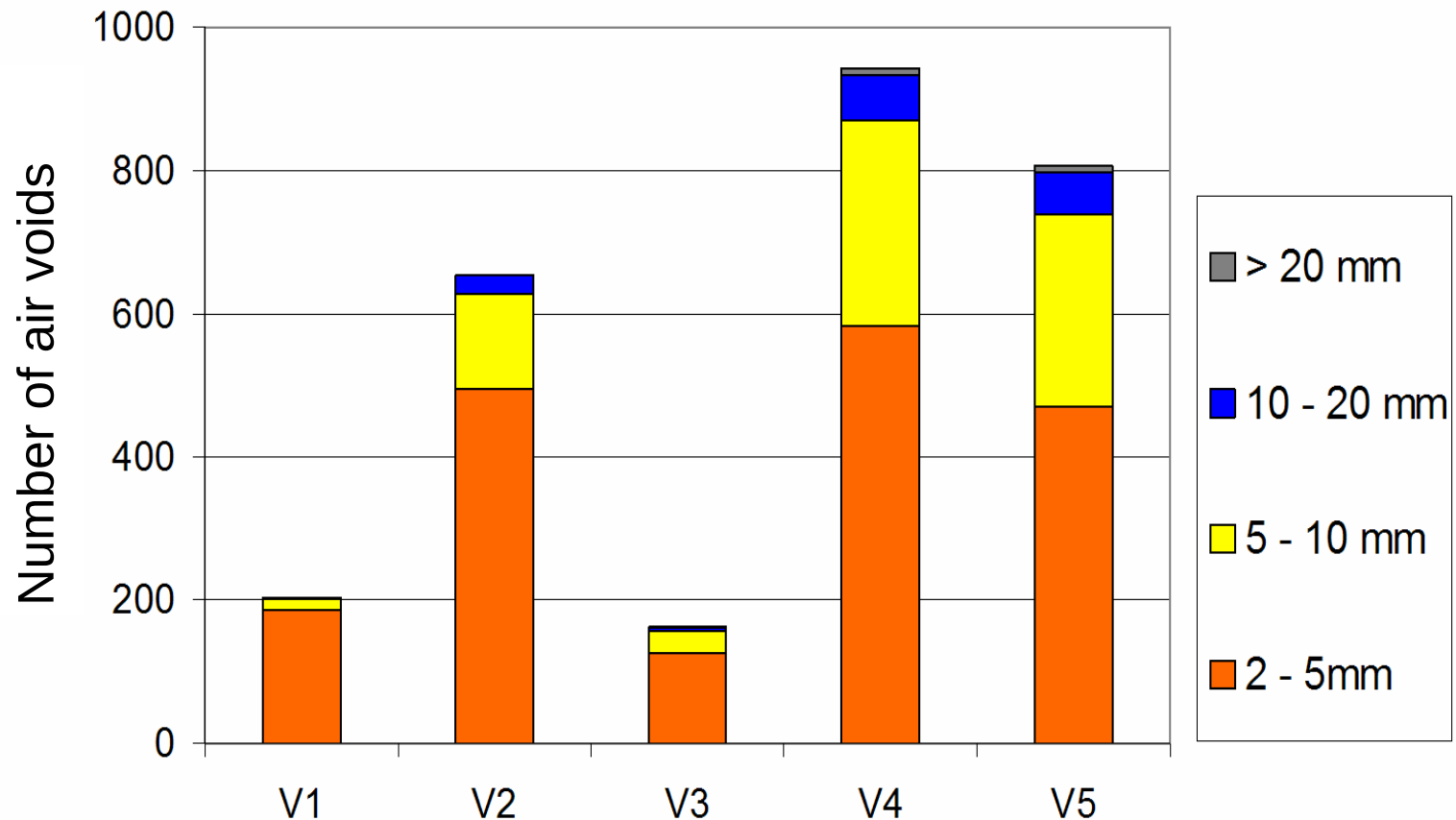
BPS-publikation 24: *Typiske beskrivelsesafsnit – indvendige betonoverflader til malebehandling og tapetopsætning* (2. udgave, 1989).

For each wall four sections are chosen of 1x1 m². The sections represent

Results



Results



The surface finish is very dependent on the casting technique and the rheological properties.

Results

According to annex F in DS 2426 concrete in exposure class XF2, XF3 og XF4 (A, A and E in DS 481), which is exposed to a combination of salt and frost should obtain:

- Air void content in hardened concrete (DS/EN 480-11) $> 3,5\%$
- Spacing factor is < 0.20 .

It is observed that all the tested samples fulfil these requirements except for the three core samples in the bottom of V1 where the total air void content is 3.4%.

Results

According to annex F in DS 2426 concrete in exposure class XF2, XF3 and XF4 (A, A and E in DS 481), should obtain the result *good* in a frost/thaw test (SS 13 72 44).

The results show that a satisfactory frost resistance is obtained.

Experiences of Civil Engineering Projects Involving SCC

2000 – 2006

Thomas Österberg

Swedish National Board of Roads

Business Unit Production and Maintenance (SNRA,P&M)

Present situation (Civil Engineering)

- 7 years of experiences using SCC in civil engineering projects has not led to a wide use (only a few percent today)
- Why this sparse use of SCC in Sweden?

Problems with variations in consistency

Lack of practical experience at site

Too expensive!

Problems with homogeneity in hardened state

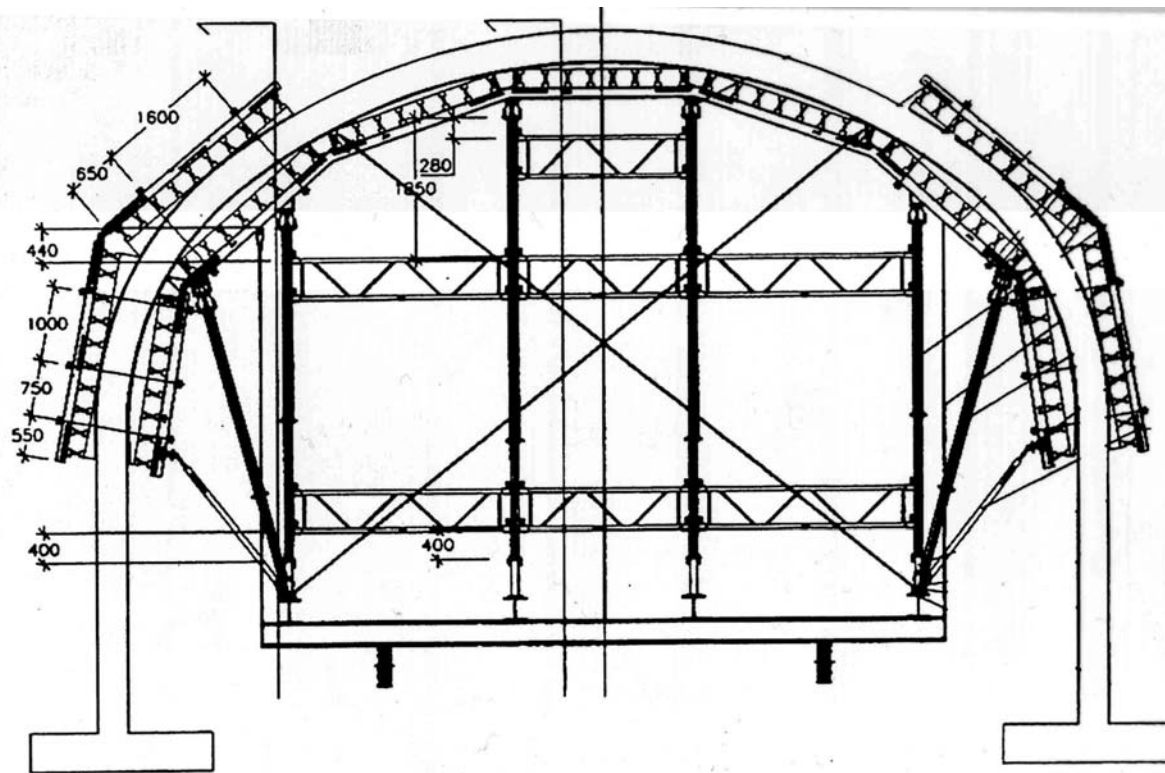
Seldom available outside urban areas

.....

Constructions where SCC has successfully been used by SNRA, P&M

- **Retaining walls**
- **Concrete arches**
- **Entrance arches to tunnels**
- **Concrete walls and arches in rock tunnels**
- **Repair jobs, thin topping layers**
- **Closed formwork, dense reinforced structures**
(often a part of 2, 3 and 4)

Concrete arch, Kallhäll - Kungsängen



Figur 8.1 Tvärsektion av tunnel med valvform.

Mälarbanan, Kallhäll - Kungsängen



Mälarbanan, Kallhäll - Kungsängen



Finished 90 m concrete arch

Bridge B 1931, Nynäshamn



High demand of aesthetics, negative inclination

SL 25 Värmdöleden, concrete arch at tunnel entrance



Dense reinforcement, high demands of aesthetics

SL 25 Värmdöleden, tunnel entrance



Detail, surface cast against Plywood

SL 01 Tpl Huddingevägen, rock lining



Dense reinforcement, closed formwork

SL 01 Tpl Huddingevägen, concrete arch & rock lining



SL 20 Årsta, retention walls



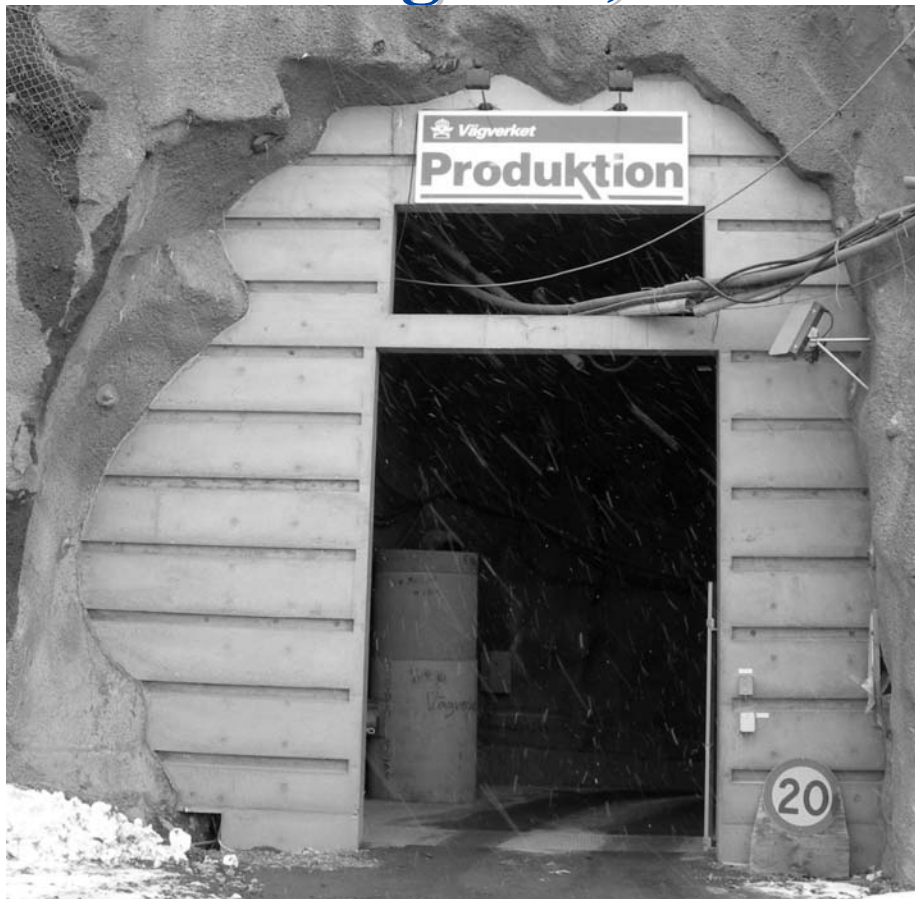
Nice surfaces despite the negative inclination and structural elements

SL 04 Nobelberget, walls in emergency evacuation tunnels



The walls were cast with SCC pumped trough valves into a closed formwork, in order to obtain tightness to the rock surface

Götaleden, maintenance tunnel entrance at Stora Badhusgatan, Göteborg



7* 5 meters. Cast with valves. Casting time 2 hours!

Stora Badhusgatan, Göteborg



Close up!

Bridge Z 799, Lillån Jämtland



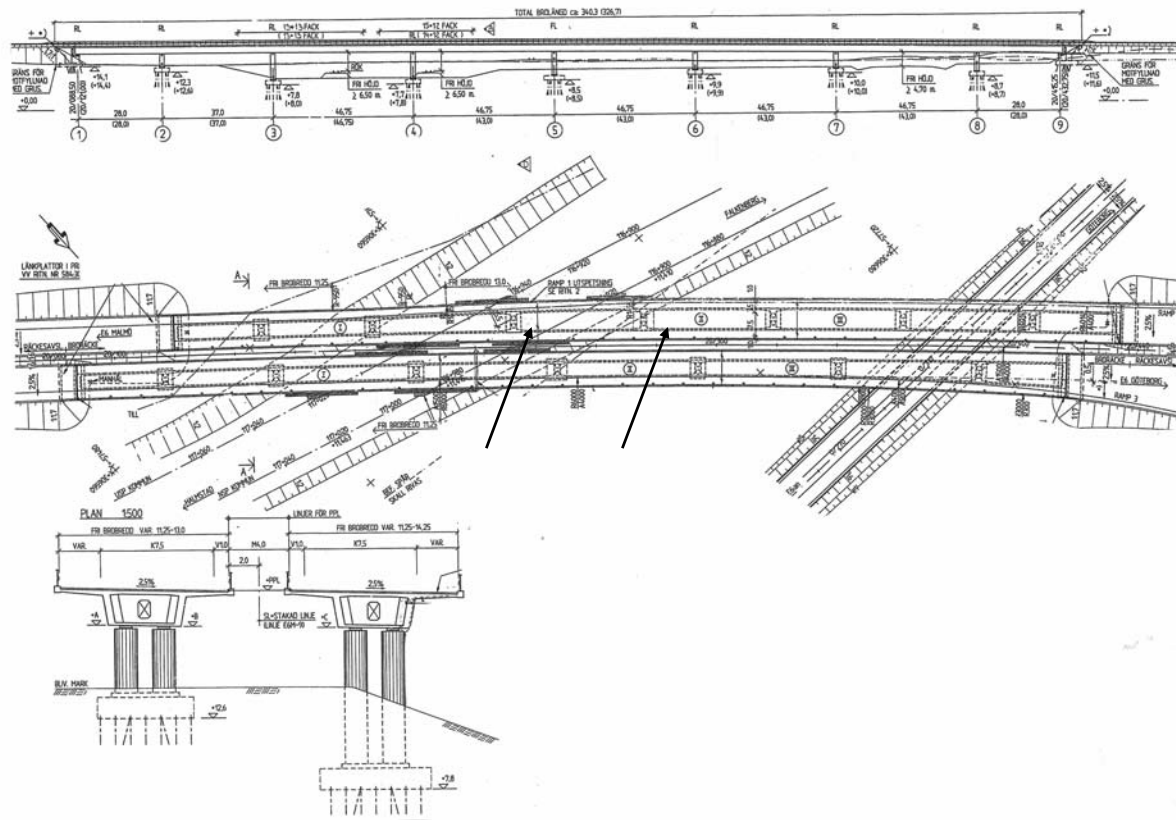
Repair of ice damaged supports, concrete topping 8-10 cm

Bro Z 799, Lillån



Finished job

Bridge N 844 at Falkenberg, Sweden



Heavy fire damaged concrete on a length of appr. 40 m

Bridge N 844 at Falkenberg, Sweden



A thin (4- 6 cm) layer of SCC was cast on fire damaged and water jetted parts of the under side

Bridge N 844 at Falkenberg, Sweden



Finished bottom of beam

Bridge N 844 at Falkenberg, Sweden



Part of east console and beam

Why was SCC chosen by SNRA P&M in this projects?

- It was not possible to compact the concrete by the use of pokers or vibratos (closed formwork)
- High amount of reinforcement. Not possible to survey the compaction process (conventional)
- A way to achieve better surfaces (especially at structures with negative inclinations)
- Less colour variations, less pores and potholes
- The combination of self compactability and high strength has in some cases turned out to be an attractive alternative to conventional compacted normal strength concrete

Conclusion: Our experiences using SCC in a number of different projects, 2000 - 2006 are generally positive, used at selected structures and cast with a close monitoring of delivered concrete!



norden

Nordic Innovation Centre

Nordic Innovation Centre

The Nordic Innovation Centre initiates and finances activities that enhance innovation collaboration and develop and maintain a smoothly functioning market in the Nordic region.

The Centre works primarily with small and medium-sized companies (SMEs) in the Nordic countries. Other important partners are those most closely involved with innovation and market surveillance, such as industrial organisations and interest groups, research institutions and public authorities.

The Nordic Innovation Centre is an institution under the Nordic Council of Ministers. Its secretariat is in Oslo.

For more information: www.nordicinnovation.net