



**RMCAO**



**Best Practices Guidelines  
for  
Self-Consolidating Concrete**

Prepared by Ready Mixed Concrete Association of Ontario – January 2009

# Best Practices Guidelines for Self-Consolidating Concrete

## TABLE OF CONTENTS

What is Self-Consolidating Concrete? .....	3
How to Utilize SCC Effectively on Your Projects .....	3
Selection Process for SCC Applications.....	3
Engineering Properties of SCC .....	3
Test Methods for Evaluating SCC.....	4
SCC Production Requirements.....	6
Site Preparation Requirements for SCC.....	7
SCC Placing & Finishing .....	9
SCC Appearance and Surface Finish .....	11
Sustainable Construction Considerations .....	14
References .....	14
Appendix A – Full Size VSI Pictures .....	15



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## WHAT IS SELF-CONSOLIDATING CONCRETE?

**Self-Consolidating Concrete (SCC)**, also referred to as self-compacting concrete, is able to flow and consolidate on its own. At the same time it is cohesive enough to fill spaces of almost any size and shape without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily reinforced concrete members or in complicated formwork.

This technology, developed in Japan in the 1980s, is based on increasing the amount of fine material without changing the water content compared to conventional concrete. This changes the rheological behaviour of the concrete and produces the outstanding flow characteristics that are required for production.

SCC is highly flowable, non-segregating concrete that can spread into place under its own weight to fill formwork and encapsulate extremely congested reinforcing steel, with little or no mechanical vibration. SCC's unique properties give it significant economic, constructability and aesthetic performance on conventional construction projects. SCC allows for rapid concrete placement with significantly reduced labour requirements, consolidation and finishing. The outstanding flow characteristics of SCC can also result in dramatically improved surface finishes. Its use for architectural applications is increasing significantly.

## HOW TO UTILIZE SCC EFFECTIVELY ON YOUR PROJECTS

While SCC has been commercially available for over 10 years in the Ontario marketplace, some owners, consultants and contractors have yet to utilize this product on their own projects. Since SCC has such dramatically improved placement and finishing properties, there is a need for new users to spend some time becoming familiar with the product prior to concrete placement.

Some key areas that will be addressed by this document include:

- Selection Process for SCC Applications
- Engineering Properties of SCC
- Test Methods for Evaluating SCC
- SCC Production Requirements
- Site Preparation Requirements for SCC
- SCC Placing & Finishing
- SCC Appearance and Surface Finish

## SELECTION PROCESS FOR SCC APPLICATIONS

While it is possible for Consultants and Owners to specify the use of SCC directly in their tender documents, this product has also often been selected for use by the

contractor due to the dramatically increased performance and production efficiencies that can be achieved.

From a constructability standpoint SCC offers the following key benefits:

- Elimination of the need for internal vibration of the concrete
- Extreme ease of placement and flowability
- Ability to fully encapsulate heavily congested reinforcing steel applications
- Rapid rate of concrete placement
- Significant reduction in concrete placement crew sizes
- Dramatically improved concrete surface finish
- Excellent durability properties with a low W/CM ratio and potential for high early strength development
- Reduction of on-site noise to address local by-laws or community concerns



These significant performance improvements with SCC also create some new constructability issues for both specifiers and contractors that must be considered and planned, for a smooth transition into this product's use. The remainder of this guide attempts to address these new constructability issues and to provide general guidance for the effective use of SCC on projects.

## ENGINEERING PROPERTIES OF SCC

Self-Consolidating Concrete and conventional concrete that is vibrated to properly consolidate have similar compressive strength and performance properties. While compressive strength is the most common property used in concrete evaluations, there are other important material properties that need to be considered. The typical performance properties include:

- **Compressive Strength** – SCC will typically have a slightly higher compressive strength when compared to a conventional concrete of similar w/cm ratio. This is due to the improved interface between the aggregate and the hardened paste.

- **Tensile Strength** – For a given concrete strength and maturity the tensile strength can normally be assumed to be the same as conventional concrete. This is due to the fact that the paste volume has no significant impact on tensile strength.
- **Modulus of Elasticity** – The modulus of elasticity is often the controlling parameter in slab design and post tensioned concrete elements. Since the bulk of the concrete is aggregate, the aggregate modulus of elasticity has the most impact on this value. However, the increased volume of paste in SCC can decrease this value slightly.
- **Creep** – Is the gradual increase in deformation with time under a constant applied stress. Creep takes place in the cement paste and is influenced by porosity, w/cm ratio, type of cement, and volume of aggregate available to restrain the creep. Due to the higher volume of cement paste in SCC, creep is expected to be higher than conventional concrete.
- **Shrinkage** – Shrinkage is the sum of autogenous (during hydration) and drying shrinkage (loss of moisture over time). SCC mixes typically exhibit similar shrinkage characteristics to conventional concrete mixes.
- **Coefficient of Thermal Expansion** – Coefficient of thermal expansion of concrete varies with its composition, age and moisture content. SCC typically exhibits similar properties to conventional concrete.
- **Bond to Reinforcement** – Reinforced concrete design is usually based upon the assumption of an effective bond between the rebar and the concrete. The effectiveness of this bond is affected by the position of the reinforcing steel and the quality of the concrete. While SCC bond strength is typically assumed to be higher than conventional concrete, this increase in bond is typically not considered in the design of the structure.
- **Durability** – The durability of a concrete structure is closely associated to the permeability of the surface layer of the concrete, with lower permeability resisting the inflow of CO<sub>2</sub>, chlorides, sulphates, water, oxygen, etc. Improper consolidation of conventional concrete results in significant durability loss which is one of the

primary advantages of SCC (hence its original development in Japan). For this reason, the durability of SCC is expected to be equal to or greater than conventional concrete.

## TEST METHODS FOR EVALUATING SCC

The majority of concrete produced in Ontario has specification requirements that are governed by the Ontario Building Code and CSA A23.1/.2 Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete. The CSA A23.1/.2 standard includes the basic and advanced test methods that can be used for evaluation and acceptance of SCC on construction projects. The only exceptions to the existing CSA A23.1/.2 testing requirements relate to the preparation of concrete samples. SCC, unlike conventional concrete, does not require internal consolidation (rodding) when preparing samples since the primary purpose of this consolidation is to remove entrapped air from the samples. In fact the rodding of SCC is more likely to result in segregation of the concrete, rather than providing a properly consolidated concrete sample for testing purposes. For this reason the standard concrete consolidation methods do not apply to SCC (i.e. cylinder moulds are filled in one lift rather than three without any rodding, plastic air tests are conducted by filling the air meter bucket in one lift without any consolidation, etc.).

The SCC evaluation and acceptance process is typically broken down into the following two phases: pre-qualification testing acceptance (if necessary) and jobsite product evaluation.

The pre-qualification testing and acceptance process can include the following components:

- Submission of a performance based mix design which identifies all of the structural and constructability properties of the concrete
- Documentation of past SCC performance on completed projects
- Any specified prequalification testing. This may include:
  - Slump flow test results & Visual Stability Index (VSI) evaluation
  - T<sub>50cm</sub> Time
  - V-Funnel test
  - J-Ring test
  - L-Box test
  - Column Segregation test

Jobsite product evaluation typically consists of:

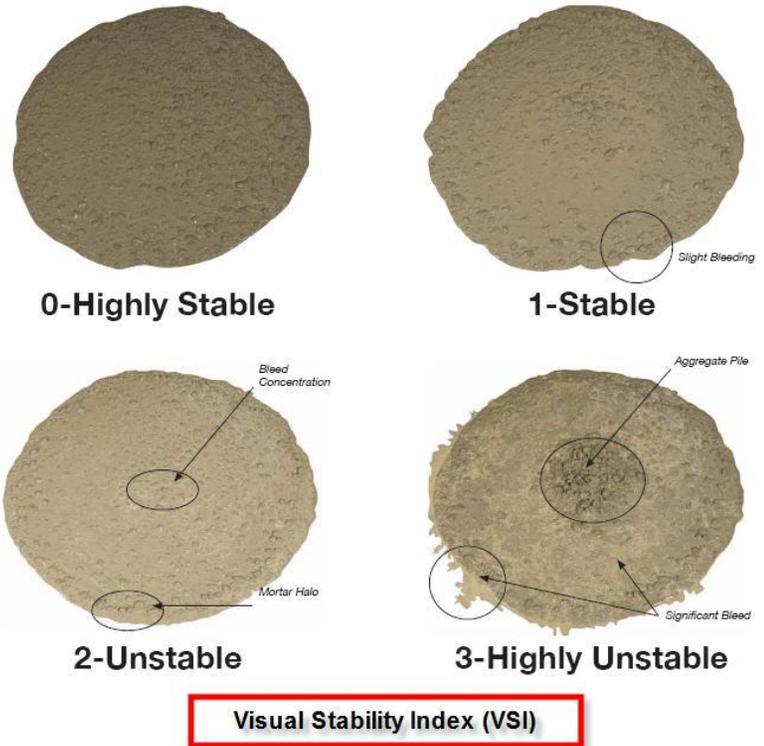
- Conducting slump-flow tests to confirm the plastic properties of the product.
- Conducting Visual Stability Index (VSI) evaluations of the product.
- Conducting typical hardened property testing (strength evaluation, permeability, etc.).

The various SCC test methods that can be used to evaluate the product during the prequalification and jobsite acceptance periods are:

- **Slump Flow** – This test method evaluates the ability of the SCC to flow under its own weight in an unconfined condition. This test method involves filling an inverted slump cone full of SCC without consolidating the material on a non-absorbent rigid surface, lifting the slump cone and measuring the diameter of the resulting “SCC patty” that is formed. This is usually the primary acceptance test method used on the jobsite and CSA A23.1/.2 requires a slump flow value between 500 – 800 mm. This test method is used for jobsite acceptance.

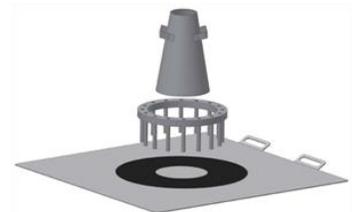


- **Visual Stability Index (VSI)** – The stability of self-consolidating concrete can be assessed by visually evaluating the distribution of the coarse aggregate within the concrete mass after the spreading of the concrete has stopped. Typically once the slump flow test has been completed, a visual stability index value is assigned to the concrete. The VSI values range from 0 to 3 and are defined as follows:
  - **0 = Highly Stable** – No evidence of segregation or bleeding.
  - **1 = Stable** – No evidence of segregation and slight bleeding observed as a sheen on the concrete mass.
  - **2 = Unstable** – A slight mortar halo ( $\leq 10$  mm) and/or aggregate pile in the centre of the concrete mass.
  - **3 = Highly Unstable** – Clearly segregated by evidence of a large mortar halo ( $\geq 10$  mm) and/or a large aggregate pile in the centre of the concrete mass.



VSI values of 0 or 1 indicate acceptable SCC. VSI values of 3 clearly indicate SCC that should be rejected. VSI values of 2 indicate that the concrete is unstable and the mix design should be immediately modified to obtain a VSI value of 0 or 1 (i.e. site addition of viscosity modifying admixtures, etc.). See Appendix A for full size VSI pictures.

- **T<sub>50cm</sub> Value** – The T<sub>50cm</sub> value is recorded during the slump flow test by pre-marking a 50 cm diameter circle on the non-absorbent rigid surface and using a stopwatch to record the amount of time that is required for the concrete to reach this diameter. This test method provides additional information regarding the segregation resistance and uniformity of the SCC. This test method also provides information on the viscosity of the product. This test method can be used for jobsite acceptance.
- **V-Funnel Test** – This test method is used to measure the flowability and dynamic stability of the SCC mixture. The test consists of a V-shaped funnel capable of holding 12 litres of SCC and equipped with a gate on the bottom of the device. The funnel is filled with SCC and the time required for the



material to follow out is recorded. The test can also be completed with a second sample held in the funnel for 5 minutes and the result V- funnel time can be compared to the initial reading. This test method evaluates the viscosity of the SCC and its ability to flow through a restricted opening without segregation. This test method is typically used for product prequalification.

- **J-Ring Test** – The same test procedure used in the slump flow test is followed with the exception that a J-ring device is placed at the base of the slump cone. When the slump cone is then raised the SCC must flow around the bars of the J-ring as gravity consolidates the material. The J-ring simulates the presence of reinforcing steel in the structure. This test method is typically used for product prequalification but may also be used for jobsite acceptance.
- **L-Box Test** – This test method is used to evaluate the flow properties and passing ability of SCC when confined by formwork and forced to flow around reinforcing steel. The test method consists of placing SCC inside the upper portion of an L-shaped box and measuring the height of the concrete once the gate is opened and the SCC flows around the rebar and 800 mm down the bottom of the L-box. This test method is only used for product prequalification.



The typical remaining evaluation properties of SCC are maximum w/cm ratio and compressive strength. The maximum w/cm ratio requirements are met by the concrete producer during the mix design development stage and the compressive strength is evaluated using standard CSA A23.1/.2 testing protocols (with the exception of not consolidating the concrete sample during casting).

## SCC PRODUCTION REQUIREMENTS

Self-Consolidating Concrete is less tolerant to changes in properties and volumes of the raw materials used to produce the mix than conventional concrete. It is therefore

very important that all aspects of the production and placement process are carefully supervised.

From a concrete production standpoint, the following steps should be taken:

- The concrete plant and mixing/delivery equipment shall all be RMCAO certified.
- The concrete producer shall submit to the contractor, for review by the owner, the performance based mix design submission which clearly indicates the performance properties of the concrete.
- The concrete producer will conduct any trial batch testing and prequalification that is specified in the contract or submit test results from a previous SCC placement conducted within the last 12 months.
- The concrete producer should designate, for each placement over 50 m<sup>3</sup>, a quality control technician to monitor and evaluate the SCC product at the plant or jobsite to confirm its suitability for use.

The next critical production issue is determining the method of site acceptance at the project and the associated acceptance criteria. This standard acceptance process is for the contractor to inspect the delivery tickets for each load of concrete to confirm the correct material has been shipped to the project and then to conduct concrete acceptance testing as per CSA A23.1/.2 requirements.

All concrete Field testing must be completed by a CSA or ACI certified field technician as per CSA A23.1 requirements: all laboratory testing shall be completed by a CSA Certified Concrete Laboratory. The standard acceptance test method for SCC is the slump flow test and VSI evaluation. The performance based mix design submission will indicate the minimum and maximum slump flow or the acceptable slump flow range for jobsite product acceptance and the acceptable VSI values for concrete placement (typically 0 & 1). This test method provides a good indication of the uniformity of concrete supply and



allows for a visual assessment of potential mortar/paste separation around the outside circumference of the sample.

All CSA A23.1/.2 testing requirements must be followed to ensure that the jobsite acceptance testing is properly evaluating the performance of the SCC mixture.

## **SITE PREPARATION REQUIREMENTS FOR SCC**

One of the key advantages to SCC is the fact that its high flowability allows for rapid discharge on the jobsite with minimal concrete placement labour required. The keys ensuring proper concrete placement from a contractor standpoint are:

- Confirming that the proposed SCC mix design is appropriate for the actual project site conditions prior to ordering.
- Selecting an appropriate delivery rate and time with the concrete producer.
- Clearly documenting the jobsite acceptance test methods and ensuring that the owner, concrete producer, contractor and testing company, are all aware of the acceptance procedures (typically slump flow testing).
- Ensuring that the concrete placement crew is aware of the significant differences between SCC and conventional concrete prior to first working with the material.
- Ensuring that the formwork is properly designed and constructed to both support the weight of the concrete and to provide the necessary concrete surface finish the Owner requires.

### **Site Control Tests**

A quality control procedure for SCC involves first confirming that the correct concrete mix has been shipped to the project (via the delivery ticket) and then conducting plastic concrete acceptance testing on the product.

Concrete acceptance testing usually involves:

- Conducting slump flow testing and VSI evaluation on each load of concrete. This confirms that the minimum slump flow value has been achieved and allows for a visual observation and rating of the material.
- Conducting plastic air content testing for exterior concrete exposure conditions or when compressive strength samples are cast.
- Casting compressive strength test cylinders for later hardened concrete testing. Cylinders are filled in one lift without any internal consolidation (rodding).

## **Mix Design Adjustments**

In general, the site adjustment of SCC mix designs is undesirable. SCC mixtures require a very high level of raw material testing and batching accuracy at the concrete plant and typically shouldn't require any jobsite adjustments. If special circumstances exist or if the mix design requires unanticipated optimization to meet the actual jobsite placement requirements then these modifications should only be made by the concrete producer. All site modifications made to the SCC mix must be hand written on the concrete delivery tickets.

### **Site Supervision**

It is critical that the site personnel receiving and placing the SCC be properly trained and educated in the unique requirements of this concrete product. In particular, the placement crew should be aware of:

- Formwork design considerations
- The effects of vibration on the SCC mixture
- The effects of stoppage during the concrete placement
- The maximum rate of concrete placement to ensure that the formwork system isn't overloaded
- Visual checks should be made of the concrete to ensure segregation is not occurring inside the formwork
- The requirements for placing SCC via a chute, a bucket or a concrete pump
- How to properly finish the surface of the SCC
- What are the minimum curing requirements of SCC

As stated later in this document, placement technique and formwork quality are the key factors that dramatically affect the quality of the surface finish of the concrete element and while these skills can all be learned on the jobsite, there are also opportunities to participate in educational training sessions from the following Ontario Associations:

- Ready Mixed Concrete Association of Ontario
- Ontario General Contractors Association
- Ontario Road Builders' Association

Alternatively, your local RMCAO member concrete producer may also offer product demonstrations and short training sessions on the use of this product.

### **Formwork Design Considerations**

The first thing to remember when it comes to SCC is the fact that the structural engineer completing the formwork design must design for a **full liquid head condition**. The high flowability and rapid concrete placement properties of

SCC allow for exceptional concrete placement rates, however the formwork has to be able to take the resulting pressures that are generated. Because of this fact, a **controlled rate of pour** formwork design is not typically used and failing to recognize this fact prior to concrete placement can result in serious formwork safety issues.

Secondly, it is possible for formwork pressures to exceed the full liquid head condition in some applications. For example, concrete placement by pump from the bottom of the formwork is often performed because of the reduced chance of air bubble being trapped up against the formwork. However, when placing the concrete using this method it is possible for the formwork pressure to exceed the full liquid head of the concrete at the location of the injection port at the bottom of the formwork.



The concrete placement crew must also be aware that since the SCC has such great flowing capabilities, it is possible for buoyant forces to be placed on components of the formwork or embedded items that are located within the formwork. For example, large size conduit will exhibit buoyant forces when the SCC is placed in the formwork and must be securely tied in place (envison a beach ball riding on the surface of the liquid SCC).



The concrete forming crew must also be aware of the highly flowable nature of the SCC and the fact that while minor gaps in the formwork may result in concrete fins with conventional concrete, SCC can rapidly flow through these gaps resulting in significant material loss and clean-up costs. Also, since this material rapidly seeks to level itself due to gravity, the entire formwork system must be fully constructed and

inspected prior to SCC placement. Failure to initially recognize the flowing properties of SCC has resulted in unnecessary concrete placement problems (forgetting to seal around formwork penetrations or thinking that the concrete placement is so far away that you still have time to finish the formwork are common first time mistakes).

### Surface Quality of the Formwork Material

One of the major benefits to SCC is the fact that it produces an outstanding concrete surface finish. The forming contractor must, however, remember that SCC perfectly mirrors the quality of the formwork that it is cast against and the owner's architectural expectations are often much higher for this product. Minor imperfections in concrete formwork might be hardly noticeable with conventional concrete, but can stand out significantly when SCC is used. If the primary purpose for using SCC is to aid in proper concrete placement, and the concrete is not visible in the completed project, this isn't an issue. If, however, the concrete is exposed to view, things like residual concrete on reused formwork, grain patterns in the forming material, and gaps in the formwork suddenly stand out significantly when surrounded by a high quality concrete surface finish.

For commercial projects, it is best that any applications where the SCC concrete is exposed to view be treated as architectural concrete elements in the contract specifications. This allows the concrete forming contractor to account for the necessary quality of the formwork that will be used for these elements.



In order to address the forming surface finish issues many contractors utilize high quality steel forms, resin impregnated form ply or commercial form liners, to provide the architectural quality that the owner has specified. Impermeable, smooth and clean forming surfaces usually produce the best surface finish.

### Formwork Release Agents

The proper selection of form release agents for SCC projects is a critical activity for the formwork contractor since they can have a dramatic effect on the quality of the formed concrete finish. Greater care must also be taken when applying these materials since excess form release agents can result in staining and retention of air bubbles at the formed surface.

Vegetable, mineral or water based form release agents need to be applied as thinly as possible and are often just wiped on with a cloth rather than by using a hand sprayer. Modification or cutting of the form release agents to increase their coverage can also have very dramatic negative consequences to the surface finish of the concrete.

In applications where high concrete sections are being formed, such as columns and bridge piers, the form release agent not only has to be applied thinly but it must also have a strong bonding ability to prevent it from being pulled off the formwork due to the force of gravity. The forming contractor not only must select the correct form release agent for SCC, but they must also ensure that the product adheres well to the formwork they are using (wood, steel, plastic, fibre, etc.).

SCC mixtures are typically designed to allow entrapped air to escape between the contact surface of the formwork and the concrete itself. For this reason the form release agent must be of a type that will allow air to migrate along this surface and to be expelled at the top of the formwork. When first utilizing SCC the contractor should contact the form release agent supplier and confirm which of their products works best with SCC. Trial placements and mock-ups on larger projects can also be very useful for evaluating the performance of the form release agent with the SCC mixture.

### Uncoated Wooden Formwork

Unless the owner is requesting “rough wood grain pattern” for their SCC project, the formwork contractor should avoid using dry uncoated wooden formwork that is strongly absorbing and may result in discolouration, staining or retarding of the concrete surface. Surface defects will also often result during the formwork removal process where the rough grain texture of the wood bonds to the concrete or becomes trapped in the concrete and breaks off during formwork removal.



Architectural form liners are also available if the owner requires a high quality architectural pattern.

### SCC PLACING & FINISHING

SCC is designed to provide both high cohesion and high flowability under its own weight. This allows for rapid concrete placement and flow characteristics without the larger coarse aggregate segregating out of the mix. Because of this, standard internal or external vibration is not typically required to properly consolidate this material. Failure to recognize this fact will result in the potential for dramatic segregation of the material if the workers continue to utilize conventional concrete consolidation techniques. In short, don't touch it! If it has been designed and placed properly it will flow on its own. If minor rodding is required to ensure complete flow this issue should be raised directly with the concrete producer at the time of placement.

With this said, it is still necessary for the concrete finisher to continue to visually assess the quality of the SCC as it is being placed in the formwork. The worker in this instance is looking for potential segregation issues and wants to see coarse aggregate uniformly spread throughout the entire concrete placement and “floating” on the surface.

Once the concrete placement is complete, the concrete finishers should examine the quality of the hardened concrete looking for instances of surface laitance, a non-uniform surface colour, specific areas where air bubbles are being trapped on the formed surfaces and any other unwanted defects. Addressing these issues that do arise will involve reviewing the mix design performance, quality of the formwork surfaces, ability of the form release agents to work effectively and the placement method utilized for the element.

High quality surface finishes are a significant architectural benefit for the use of SCC, however they can only be achieved when highly effective mix designs, concrete formwork, and placement methods are utilized. If everyone involved in the construction process does not realize the importance of all these factors, the final product will never meet its ultimate potential.

### SCC Discharging

SCC can be placed utilizing most standard concrete placement methods including: chute, buckets and concrete pumps. While other placement methods like buggies and conveyor belts may be used, the contractor must ensure that the material is not vibrated to the point that the coarse aggregate begins to separate out.

SCC shall be discharged within the 120-minute time requirement of CSA A23.1 unless the concrete producer has taken the necessary steps to properly retard the mixture. The excellent flow characteristics of SCC typically result in rapid truck unloading, and agitation action of the concrete truck drum ensures uniformity and prevents material segregation.

### Placing Procedures and Rates

Due to the rapid placement rate of SCC, it is extremely critical that all formwork, reinforcing steel and embedded items be properly secured prior to the start of the unloading process. The concrete must also be placed in such a manner that there is sufficient distance for the concrete to flow so that entrapped air can be removed from the material, but not so far as to risk material segregation. Generally, flow lengths of 10 metres or less are preferred to avoid these issues (this doesn't mean that longer lengths can't be achieved, they just require additional efforts and care).

For large vertical elements care should be taken not to fill the formwork too rapidly. The placement rate should be slowed to the point that there is sufficient time for the entrapped air to rise to the concrete surface. Since air movement can only take place when the SCC is itself moving into the formwork, slowing the placement rate may assist in removing unwanted air pockets at the formed face of the concrete. The placement process should also be smooth and continuous since this helps maintain uniform SCC flow and reduces surface marks and colour variations. For this reason SCC is often placed using concrete pumps with multiple concrete trucks supplying the feed hopper of the pump.

### Pumping SCC

Placing SCC using a concrete pump is one of the most common placement methods. Pumping places the concrete as close as possible to its final position and provides an easily controlled rate of placement.

When placing SCC with a concrete pump the hose of the pump should be placed inside the formwork and under the concrete surface whenever possible. This installation method both reduces the possibility of entrapping additional air within the SCC and eliminates the potential for material segregation due to free-fall around the reinforcing steel and form hardware.

Pumping should provide a continuous even concrete rise rate within the formwork with as few breaks in product delivery as possible.

### Pumping SCC from the Bottom Upwards

SCC's performance properties allow for unique concrete placement methods. One of the most common special placement methods is to install a fill port on the bottom of the formwork and utilize a conventional concrete pump to place the concrete from the bottom up.

This unique placement technique offers a number of technical advantages over vertical drop placement, since it reduces both the potential for material segregation and the amount of entrapped air that must be expelled from the concrete.



The contractor must design an injection port in the formwork that is able to resist more than the total liquid head force since concrete pumping pressures must also be accounted for. The injection port is typically located at the centre point of the formwork from a plan view standpoint to equalize the horizontal movement requirements of the SCC during the pumping process. Once the concrete placement is complete, the valve on the injection port is closed and the concrete is allowed to set. The port can then be cut off at the form face to allow for formwork removal.

### Placing Concrete Using Chutes

While concrete pumping is the preferred method for SCC placement, concrete chutes can also be utilized. The basic procedure is similar to conventional concrete placement where chute placement takes place at the farthest location and the chutes are moved or removed during the concrete placement as the work proceeds to the other end of the formwork. Care should be taken to minimize vertical drops to 1.5 metres or less and to minimize horizontal flow to 10 metres or less.

Since SCC has such high flowability, conventional concrete placement methods that involve the temporary removal of formwork to allow for concrete truck access to the area (say on an unreinforced



industrial floor slab cast on grade) cannot be used since the concrete is so highly flowable.

### Concrete Placement by Crane & Bucket

SCC placement has also been successfully completed using concrete buckets on high rise construction projects. Some of the key considerations for this placement method are the following:

- The bucket method significantly reduces the potential placement rate of the product and is typically only used for smaller volume placements (concrete columns rather than suspended floor slabs).
- The slow placement rate can result in prolonged periods of stagnation of the SCC within the formwork. This can result in surface crusting and can lead to visible horizontal marks between lifts.
- The bucket must be in excellent condition and be “water tight” or the SCC paste will easily flow through the openings in the discharge gates.
- The concrete bucket must not be shaken excessively during the lifting process. Once the concrete is discharged from the truck mixer there is no way to properly agitate the concrete in the bucket and over-vibration of the bucket has the same effect as over-vibration of the formwork.
- When SCC is placed in high thin elements, the concrete should be placed with the use of an elephant trunk or hose using a tremie placement method. This significantly reduces the amount of entrapped air that must be removed from the concrete and leads to a higher quality surface finish.

### Vibration of SCC

Did we mention, “**don’t vibrate SCC? Step away from the concrete with that internal vibrator!**” Vibration should generally be avoided since it is likely to result in material segregation, where the coarse aggregate sinks to the bottom of the mix.

If, upon removal of the formwork, the concrete surface is not as required, the contractor and concrete producer should review the SCC specification requirements to see if mix design changes could improve the result or if the difficulties are due to some other factor.

The potential exceptions to the SCC “**don’t touch it**” rule may include:

- In some structures the formwork shape may result in air being trapped at certain locations. This can be addressed by **localized tapping or rodding** of

the area or potentially venting the area and discarding the “vent concrete” later.

- Slabs may require light tamping or vibration using a screed bar to produce a level finish that does not include protruding coarse aggregate. The screed bar is therefore the only surface finishing performed on the concrete.
- If there is a break in the supply of SCC to the project, surface crusting may occur. In this instance, slight rodding can be used to remove the potential for the formation of a cold joint or surface discolouration.

### Curing Requirements for SCC

While curing is obviously critical for all concrete construction, this is especially true for the top surface of SCC. Because of the increased quantity of paste, low water/fines ratio and lack of bleed water at the surface, SCC is highly susceptible to surface drying. This can result in shrinkage cracks caused by early age moisture loss or surface crusting.

Initial concrete curing shall conform to the requirements of CSA A23.1 and should commence as soon as practically possible. Initial protection period treatments such as fog misting and evaporation retardants may also be useful in addressing surface curing issues.

### SCC APPEARANCE AND SURFACE FINISH

High quality concrete surfaces are what many owners expect when SCC is used on their projects, but as this document has identified, there are multiple factors that affect the final surface quality of the concrete element.

The quality of the SCC surface depends on:

- The mix composition of the product.
- The quality of the formwork surfaces.
- The quality of the formwork release agent and its interaction with the SCC mixture.
- The placing methods and procedures utilized.

The key architectural benefits that SCC mixes provide over conventional concretes include:

- More uniform colour.
- Provides very sharp edges with the use of the correct formwork.
- Significant reduction in the number of bugholes with the use of proper form release agents and formwork quality.
- Eliminates air pockets under horizontal formwork elements when the concrete is properly placed.
- Higher quality of surface finish.

The following list of defects can be found in all concrete products, however with the proper amount of care and consideration, can be significantly reduced with SCC.

### Bugholes

Bugholes are small, regular or irregular cavities, usually not exceeding 15 mm in diameter, resulting from the entrapment of air bubbles in the surface of formed concrete during placement and consolidation.

Entrapped air is introduced into all concrete during the mixing, transportation and placement processes. The extent to which the entrapped air can be removed or stabilized within the SCC depends on the cohesion of the mixture. In general, SCC mixtures with high slump flow and

low viscosity make it easier for the entrapped air to be removed and provide the best surface finish.

Bugholes are also formed on concrete surfaces when air is trapped between the formwork and the concrete. The qualities of the formwork surface and the formwork release agent therefore also have a significant impact on their formation.

Entrapped air is also most easily removed if the SCC mixture is slowly placed into the formwork and if it is allowed to move laterally for two metres or more. For these reasons pumping of the concrete from the bottom of the formwork, as described previously, generally produces the best surface finish. If this is not possible, tremie concrete placement from the top of the formwork is your next best option.

Troubleshooting Tips for Bugholes		
Primary Causes	Practical Reasons	Preventative Measures
<ul style="list-style-type: none"> <li>Entrapped air</li> <li>Entrapped water</li> <li>Entrapped form oil</li> <li>Low slump flow</li> </ul>	Heavy or uneven application of form release agent	Minimal application evenly applied
	Rough formwork surface	Clean formwork or install a geotextile form liner to absorb air
	Rapid placement rate	Ensure slower and steady discharge
	Too long a flow length	Limit flow distance to < 5 metres
	Too short a flow length	Extend flow distance to > 1 metre
	Interrupted delivery of concrete	Plan for required delivery rate
	Viscosity too high	Reduce viscosity modifying admixture dosage
	Slump flow too low (<600 mm)	Increase slump flow

### Honeycombing

Honeycombing is voids left in the concrete due to the failure of the mortar to effectively fill the spaces among the coarse aggregate particles.

In SCC projects, honeycombing can also be caused by leakage in the formwork at the joints, aggregate bridging, and voids being left behind the reinforcing steel or form hardware.

These issues in SCC are usually due to:

- Utilizing too low of a slump flow.
- The viscosity of the SCC mixture being too high.
- Using too large of a maximum coarse aggregate in the mix.
- Insufficient paste with the SCC mixture.

Troubleshooting Tips for Honeycombing		
Primary Causes	Practical Reasons	Preventative Measures
<ul style="list-style-type: none"> <li>Insufficient paste or fines</li> <li>Concrete segregation due to too low plastic viscosity</li> <li>Concrete not able to fill that part of the formwork</li> </ul>	Low paste/fines content	Increase fines content Add air entrainment
	Unsuitable aggregate gradation	Use continuous aggregate gradation
	Aggregate size too large relative to free space within the formwork	Utilize a smaller maximum aggregate size
	Leakage of paste through the formwork	Inspect all formwork prior to concrete placement and seal gaps at joints
	Placing SCC through an un-primed pump hose or elephant trunk	Prime all surfaces whenever possible

## Colour Changes

Vertical stripes at the SCC surface are rare and usually caused by bleed water accumulating at the vertical mould surface. As the bleed water flows upwards it causes wash-out of the aggregate or flotation of the form oil which leaves a visible stripe in the concrete.

The potential causes for SCC bleeding include:

- Utilizing too low of a viscosity in the mix.
- Low concrete temperatures during placing.
- Retarded set times.

Other reasons for colour variation can include:

- Uneven drying of the concrete surface (even within the formed face of elements).
- Over application of form release agents.
- Use of form release agents that are incompatible with SCC mixtures.
- Variations in the raw materials used to produce the SCC.

Troubleshooting Tips for Colour Changes		
Primary Causes	Practical Reasons	Preventative Measures
<ul style="list-style-type: none"> <li>• Colour variations along the surface</li> <li>• Differences between SCC loads</li> <li>• Vertical stripes</li> </ul>	Concrete temperature too low	Maintain concrete and in-form temperatures during winter months
	Too high slump flow and too low viscosity	Increase viscosity via either increased fines content or viscosity modifying admixture
	Retarding effect of admixture or form release agent	Reduce retarder usage Reduce water content Consider using an accelerator Use geotextile form liner
	Changes in rate of pour	Ensure continuous rate of pour throughout placement
	Utilizing plastic as curing method	Ensure uniform plastic contact with the entire surface
	Wooden formwork is absorbing paste	Use coated formwork materials or pre-wet wood before placement
	Viscosity too low or water content too high	Utilize viscosity modifying admixture Increase viscosity via fine material addition Consider the use of air entrainment

## Surface Cracking of SCC

SCC, like traditional concrete mixes, is susceptible to plastic settlement cracks over the reinforcing steel. This effect can be increased when high surface finishes are required because the mix design must be optimized to produce the highest possible flow for this application (the mix will be designed at the maximum aggregate segregation point to begin with). These cracks are normally wide but not deep,

and can be addressed by trowelling the concrete surface to close them prior to the concrete setting.

Because SCC has almost no bleed water, this product is also more susceptible to plastic shrinkage cracking that is caused when the top surface of the concrete rapidly loses surface moisture. Protective systems like fog spraying and early concrete curing can be used to address this issue as well.

Troubleshooting Tips for Surface Cracking		
Primary Causes	Practical Reasons	Preventative Measures
<ul style="list-style-type: none"> <li>• Rapid surface drying</li> <li>• Sedimentation</li> <li>• Reinforcing steel positioning</li> </ul>	Poor curing practices during initial protection period	Start curing immediately Consider fog spraying
	SCC segregation and bleeding	Close cracks prior to concrete setting Utilize a viscosity modifying admixture Consider air entrainment
	Extreme ambient placement conditions	Consider rescheduling placement Minimize extreme temperatures, low relative humidity or high wind conditions
	Deep formwork with reinforcement close to the surface	Consider repositioning the reinforcing steel

## **SUSTAINABLE CONSTRUCTION CONSIDERATIONS**

In addition to the construction based reason to use SCC in your project, there are a number of Sustainable Construction items that should be strongly considered:

1. Noise reduction on-site for community and local by-law issues.
2. Reduced R/M truck delivery time with faster unloading.
3. Reduced overall R/M truck turnaround time.
4. Reduced truck traffic emissions.
5. Reduced R/M truck fuel consumption overall.
6. Reduced time for traffic control, street control or enforcement and backup signallers.
7. Reduced project completion time with faster construction.

### **Procurement – RMCAO ECO CERTIFIED Concrete Facility Certification**

This program is designed to provide owners and customers with the highest degree of assurance that the concrete facility, company and products they have selected to supply their project, address sound and responsible Environmental and Sustainable Development Facilities management and operations, and that manufacturing

practices and protocols support their choice of Responsible Material Procurement. It identifies Environmental and Sustainable Development stewardship and responsibility of the facility's processes following LEED rating system and categories to minimize the environmental footprint.

## **REFERENCES**

The following documents have been utilized in the creation of this publication:

- CSA A23.1-04 – Concrete Materials and Methods of Concrete Construction, CSA A23.2-04 - Methods of Test and Standard Practices for Concrete – Canadian Standards Association.
- The European Guidelines for Self Compacting Concrete – European Precast Concrete Organisation, European Cement Association, European Ready-Mix Concrete Organisation, European Federation of Concrete Admixture Associations and European Federation of Specialist Construction Chemicals and Concrete Systems.
- Self-Consolidating Concrete – Concrete Delivers – National Ready Mixed Concrete Association.

**APPENDIX A**

**Visual Stability Index (VSI) – 0 – Highly Stable**



**Visual Stability Index (VSI) – 1 – Stable**



**Visual Stability Index (VSI) – 2 – Unstable**



**Visual Stability Index (VSI) – 3 – Highly Unstable**

