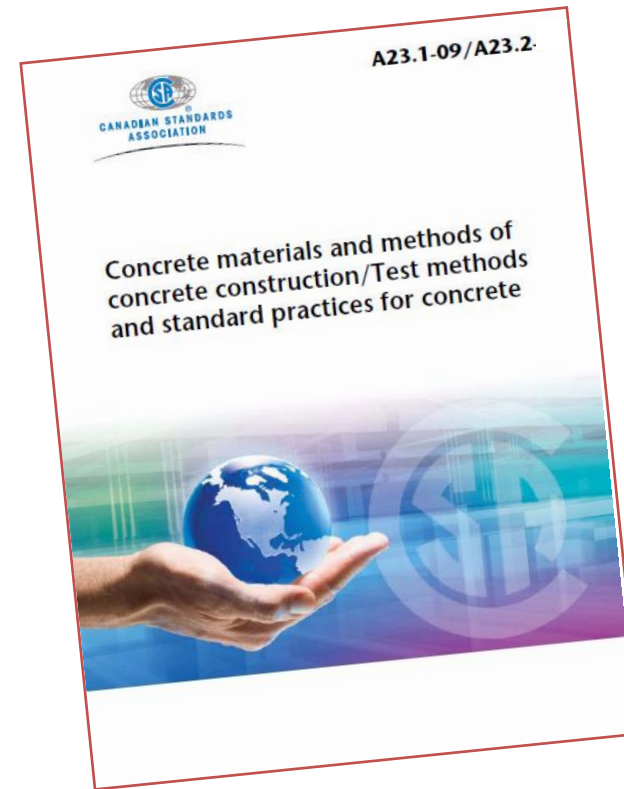


# Canadian Adoption of Performance Standards



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and Chair of CSA A23.1/A23.2



# CSA A23.1

- Since 2009, the Canadian Standards Association (CSA) A23.1 Concrete Standard has required concrete to be specified either completely by prescription or by performance.
- Prior to that, there was also a hybrid “Common” method that was a mix of both—but this confused responsibilities.
- As a result, since CSA A23.1-09 was adopted in the National Building Code, **almost all specifications in Canada have become performance-based**, since prescription implies that owners/specifiers take on the responsibilities for performance of concrete that they have prescribed.
- In the later 2014, 2019 and new 2024 editions, changes have been made to improve details and to add new performance test methods & limits

# Initially there was pushback from Designers & Specifiers

- Designers/specifiers were used to adding prescriptive limits on concrete materials and mix proportions in addition to performance.
- But this change to A23.1 basically stated that if an owner/designer added prescriptive requirements, then it was deemed to be a prescriptive spec. and they would become responsible for performance.
- Then the lightbulb came on.
- They did not want to take on that responsibility, so the performance option became the norm.

# What is a performance specification?

Canadian Standards Association (CSA): CSA A23.1

Performance requirements apply *"when the owner requires the concrete supplier to assume responsibility for the performance of the concrete as delivered and the contractor to assume responsibility for the concrete in place.*

*A performance concrete specification is a method of specifying a construction product in which **a final outcome is given in mandatory language, in a manner that the performance requirements can be measured by accepted industry standards and methods.***

*The processes, materials, or activities used by the contractors, manufacturers, and materials suppliers are then left to their discretion."*

# Key to Success with Performance Specifications

- **To achieve performance, the responsibilities of all parties need to be clearly defined in the contract documents (CSA A23.1 clearly defines these for the owner, contractor concrete supplier and testing company).**
- A performance-based specification also needs to provide a system for the owner/specifier, contractor and supplier/producer to assess and maintain quality of concrete.
- Good communication is needed to address any problems and deficiencies quickly in order to achieve the desired concrete performance.

# CSA A23.1 Performance Option

- For durability, CSA uses a [table of exposure classifications](#) to set the level of performance needed: Each exposure includes minimum requirements for concrete materials, performance properties and curing.
- The responsibilities of the owner, the supplier and the contractor are clearly defined in Table 5 with additional details provided in Annex J.
- Requirements for Qualifying concretes (for submittals) and for Acceptance Testing are now detailed in two Recommended Practices
  - A23.2-24C
  - A23.2-25C

# CSA A23.1 Exposure Categories

| Category | Relates to  | Exposure classes       |
|----------|---|------------------------|
| C        | Chlorides   | C-XL,C-1,C-2, C-4, C-5 |
| F        | Freeze-thaw   | F-1,F-2                |
| N        | Not exposed to external influences                    | N, N-CF                |
| A        | Chemical Effluents<br>(Agricultural & Biogenic Acids) | A-1,A-2,A-3,A-4        |
| S        | Sulphates   | S-1,S-2,S-3            |



# CSA A23.1-19 Table 2 Exposure Class Req'ts.

| Class of Exposure | Max. w/cm  | Min. specified strength (MPa) | Air content               | Curing     | Cement Types (or use ASTM C1012 limits) | A23.2-23C Chloride test (coulombs) |
|-------------------|------------|-------------------------------|---------------------------|------------|---|------------------------------------|
| C-XL, A-XL        | 0.40       | 50 by 56 d                    | 4-7 or 5-8% if frost exp. | Extended   | -                                       | <1000 within 91 d                  |
| C-1, A-1          | 0.40       | 35 by 56 d                    | 4-7 or 5-8% if frost exp. | Additional | -                                       | <1500 within 91 d                  |
| C-2, A-2          | 0.45       | 32 at 28 d                    | n/a                       | Additional | -                                       |                                    |
| C-3, A-3          | 0.50       | 30 at 28 d                    | n/a                       | Basic      | -                                       |                                    |
| C-4, A-4          | 0.55       | 25 at 28 d                    | 4-7%                      | Basic      | -                                       |                                    |
| F-1               | 0.50       | 30 at 28 d                    | 5-8%                      | Additional | -                                       |                                    |
| F-2, R-1, R-2     | 0.55       | 25 at 28 d                    | 4-7%                      | Basic      | -                                       |                                    |
| N                 | For design | For design                    | n/a                       | Basic      | -                                       |                                    |
| N-CF, R-3         | 0.55       | 25 at 28 d                    | n/a                       | Basic      | -                                       |                                    |
| S-1               | 0.40       | 35 at 56 d                    | 4-5%                      | Additional | HS, HSb                                 |                                    |
| S-2               | 0.45       | 32 at 56 d                    | 4-7%                      | Basic      | HSLb                                    |                                    |
| S-3               | 0.50       | 30 at 56 d                    | 4-7%                      | Basic      | MS, MSb                                 |                                    |

In 2024, bulk resistivity limits will be added as an alternative to Coulomb limits

There is also an optional drying shrinkage limit of 0.04%





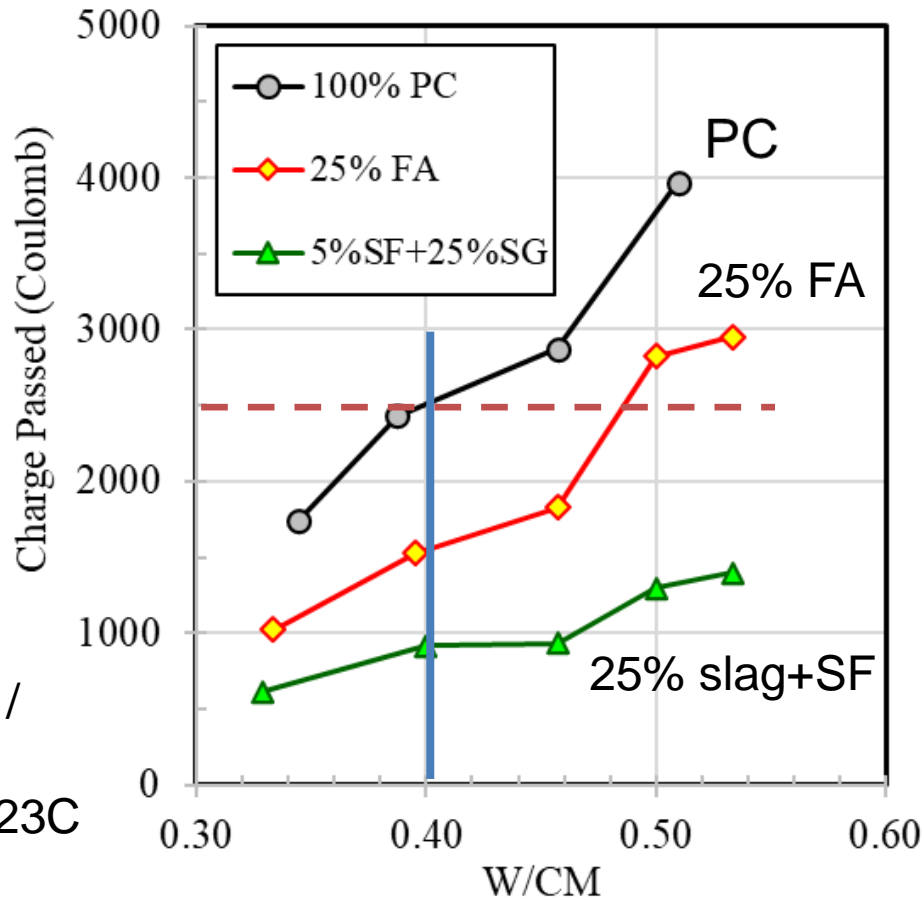
# Performance Tests for Concrete

- Typically concrete is qualified and accepted based on fresh properties such as slump/ slump flow and air, and 28-day strength is the only hardened property specified and measured.
- **28-day strength is not an adequate performance metric:**
  - Construction schedules are controlled by early-age strength development.
  - Concretes with high-SCM levels develop their ultimate properties at later ages (e.g. 56 or 91 days) Also, early strength of SCM-mixtures is underestimated by small mortar or concrete cube/cylinder tests stored at lab temperatures
  - CSA A23.1 sets strength limits for severe exposures at 56d and permeability infex tests at 91 days
- Limits based on test methods that are indicators of other properties, including durability also need to be specified.



# With SCMs, w/cm limits no longer indicate concrete of equal durability

(as indicated by permeability index)



ASTM  
C1202 /  
CSA  
A23.2-23C

M. Thomas

1. w/cm limits do not consider the impact of SCMs on permeability
2. The permeability benefits of some SCMs are not attained at 28 days. Later-age limits are more appropriate.
3. A SCM mixture at 0.5 w/cm may provide equivalent durability to a 0.4 w/c portland cement mixture.



# Performance Tests for Durability

1. **For all durability exposures:** A test that can measure or provide an index of the resistance to ingress of aggressive fluids.
2. Tests for specific exposures (as applicable):
  - ASR tests to qualify the aggregates, or to determine required mitigation, if aggregates are reactive
  - Sulfate Resistance test for chemical resistance of cementitious materials.
  - Freeze/Thaw test
  - De-icer salt scaling test.

# Alternative Rapid Index Tests for Chloride Resistance

- ASTM C1202 (coulombs):

2 days to complete

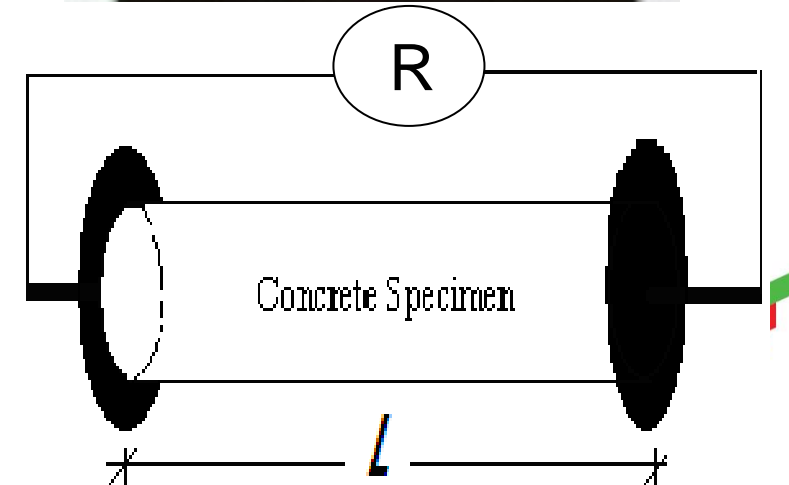
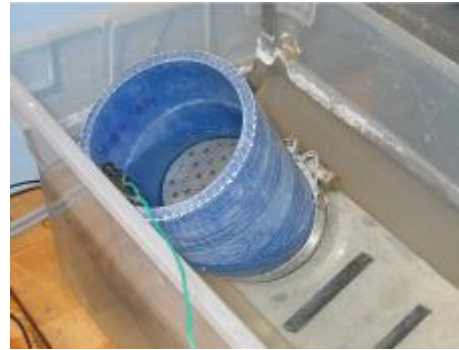
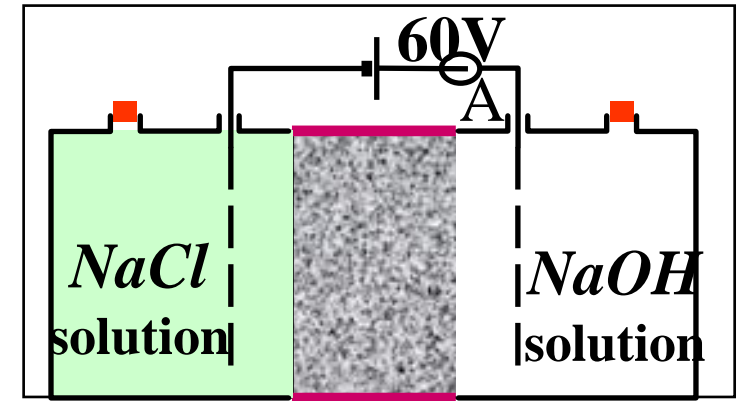
- NT Build 492:

- Bulk Resistivity:

One minute to complete

Note that saturation, conditioning fluid & temperature affect test results

$$\rho = R (A/L)$$



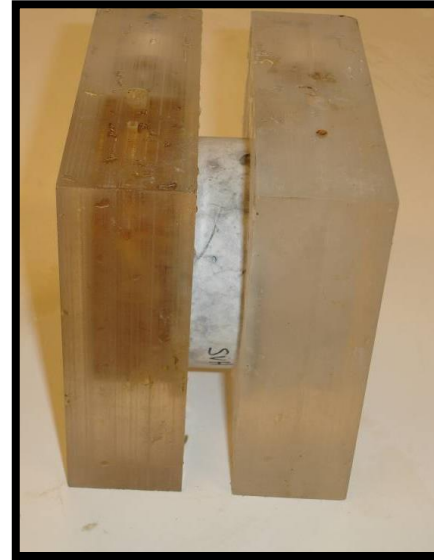
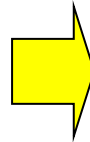
# Performance Test Limits

- Specification Limits are needed for each specified test method.
- These limits, should also allow for test variability by use of both average values and allowances for individual values to exceed those average limits due to variability inherent in the test method (similar to what is currently allowed in most specifications for occasional understrength test results).

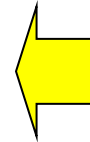
# *Specified test limits should vary with point of evaluation (Permeability Index)*



Target ~1250  
Coulombs



Specified 1500  
Coulombs



From Canadian  
CSA A23.1 for  
Class C-1  
exposure

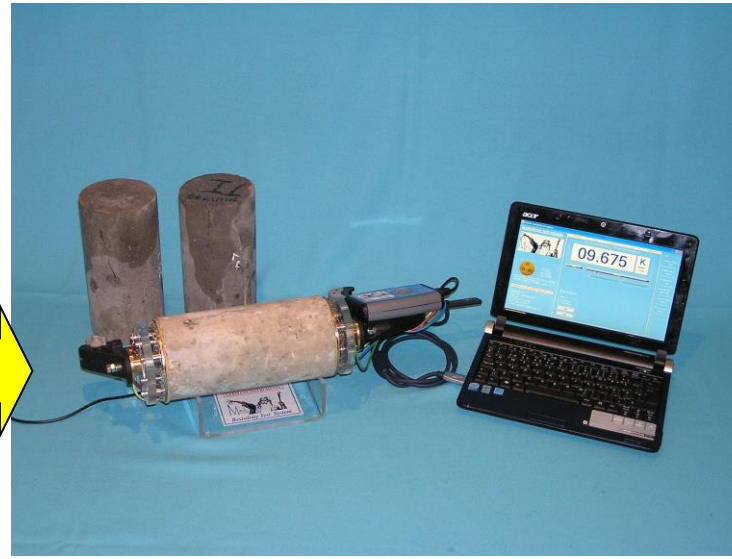
Running Average <1500 and  
no single value >1750  
Coulombs

# *Specified test limits should vary with point of evaluation (Bulk Resistivity)*



Target ~135 ohm-m

From 2024 draft of Canadian CSA A23.1  
for Class C-1 exposure



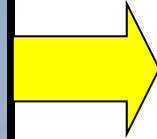
Specified 120 ohm-m



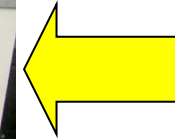
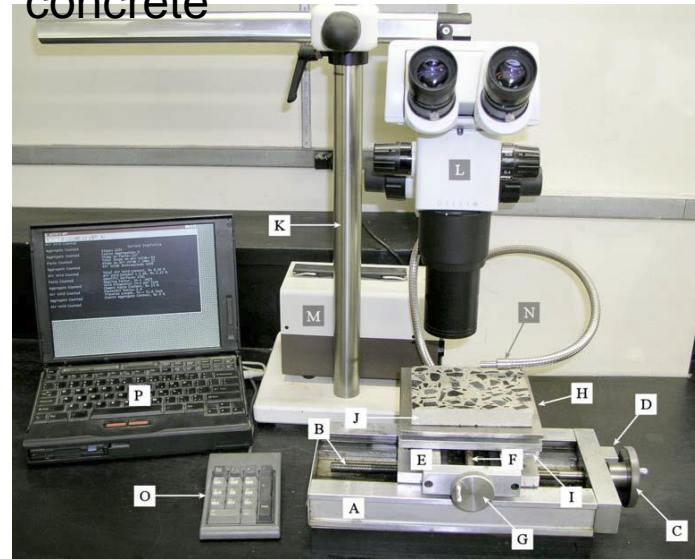
Running Average of 3 > 120  
and no single value < 105  
ohm-m

# Specified test limits should vary with point of evaluation (Entrained Air Void System )

5-8% air in fresh concrete



> 3.0 % air in hardened concrete



Target Spacing Factor ~0.17 mm

Specified = 0.23 mm

Running Average of 3 < 0.23 mm  
and no single value > 0.26 mm

From CSA A23.1 for Class C-1 exposure,  
using 20mm aggregate



# Curing Categories are part of the Performance Requirements for each Exposure Class

## Basic

- **3 d at  $\geq 10^{\circ}\text{C}$  or** until **40% of specified strength.**

## Additional (for severe durability exposures)

- **7 d at  $\geq 10^{\circ}\text{C}$  and** until **70% of specified strength.**

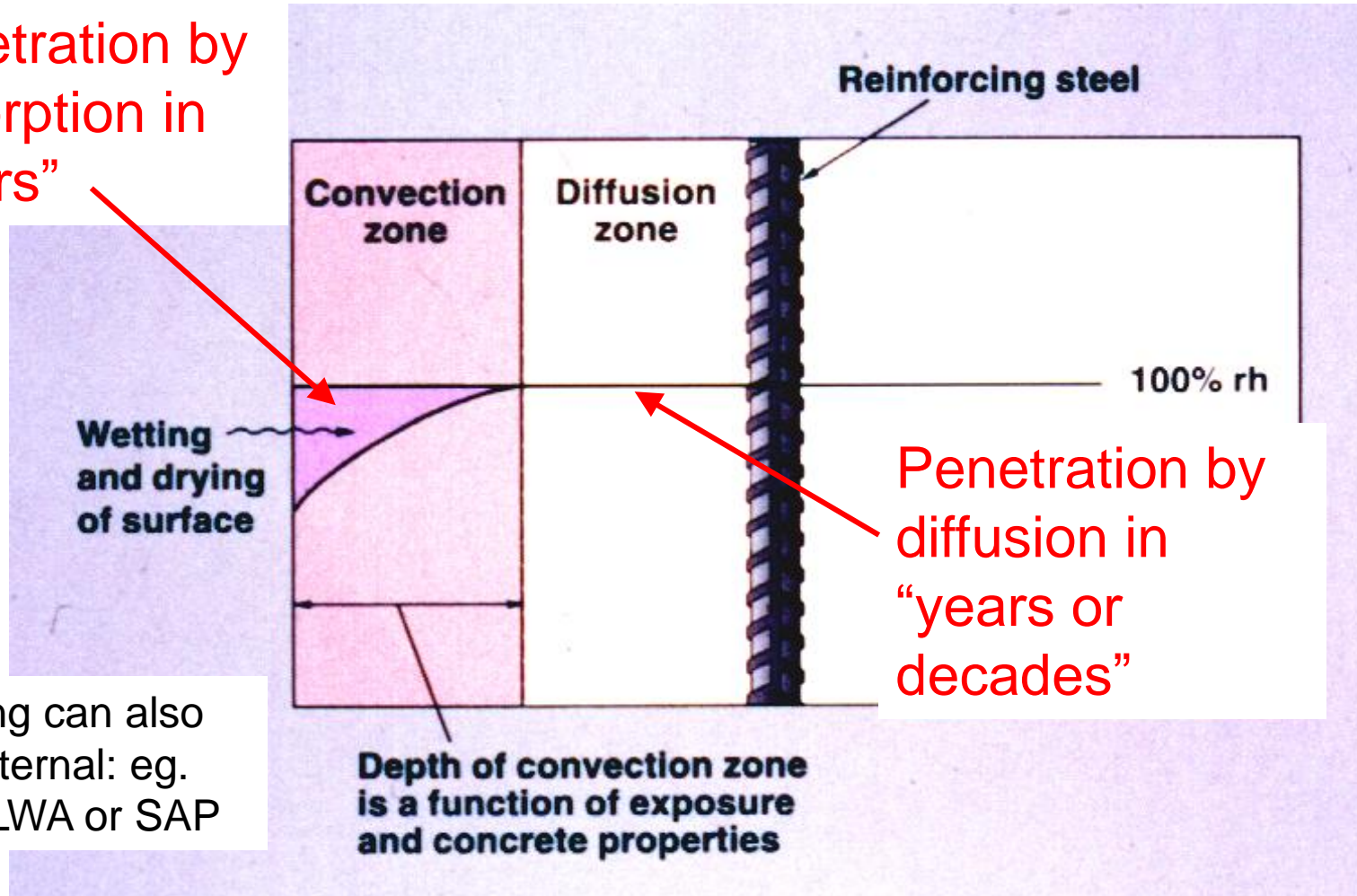
## Extended (for extended service life)

- A **wet-curing period of 7 days.** The curing types allowed are ponding, continuous sprinkling, absorptive mat or fabric kept continuously wet.

These limits are not based on durability performance, but a new performance test method will be added in 2024 to assess the relative impact of alternate curing options on rate of absorption in the curing-affected zone

# Curing directly impacts the chloride penetration resistance of the Cover Layer

Penetration by absorption in "hours"



Curing can also be internal: eg. sat. LWA or SAP

Penetration by diffusion in "years or decades"



# CSA A23.1-14 Table 5 Defines Responsibilities

**Table 5**  
**Alternative methods for specifying concrete**  
 (See Clauses 4.1.2.1, 4.1.2.3, 4.4.1.2, 4.4.1.3, and 8.1.5 and Annex J.)

Performance  
Option

Prescriptive  
Option

| Alternative  | The owner shall specify  | The contractor shall  | The supplier shall  |
|--|--|---|---|
| (1) Performance:<br>When the owner requires the concrete supplier to assume responsibility for performance of the concrete as delivered and the contractor to assume responsibility for the concrete in place. | <ul style="list-style-type: none"> <li>(a) required structural criteria, including strength at age;</li> <li>(b) required durability criteria, including class of exposure;</li> <li>(c) additional criteria for durability, volume stability, architectural requirements, sustainability, and any additional owner performance, pre-qualification or verification criteria;</li> <li>(d) quality management requirements (see Annex J);</li> <li>(e) whether the concrete supplier shall meet certification requirements of concrete industry certification programs; and</li> <li>(f) any other properties that might be required to meet the owner's performance criteria.</li> </ul> | <ul style="list-style-type: none"> <li>(a) work with the supplier to establish the concrete mix properties to meet performance criteria for plastic and hardened concrete, considering the contractor's criteria for construction and placement and the owner's performance criteria;</li> <li>(b) submit documentation demonstrating the owner's pre-qualification performance requirements have been met; and</li> <li>(c) prepare and implement a quality control plan to ensure that the owner's performance criteria will be met and submit documentation demonstrating the owner's performance requirements have been met.</li> </ul> | <ul style="list-style-type: none"> <li>(a) certify that the plant, equipment, and all materials to be used in the concrete comply with the requirements of this Standard;</li> <li>(b) certify that the mix design satisfies the requirements of this Standard;</li> <li>(c) certify that production and delivery of concrete will meet the requirements of this Standard;</li> <li>(d) certify that the concrete complies with the performance criteria specified;</li> <li>(e) prepare and implement a quality control plan to ensure that the owner's and contractor's performance requirements will be met, if required;</li> <li>(f) provide documentation verifying that the concrete supplier meets industry certification requirements, if specified; and</li> <li>(g) submit documentation to the satisfaction of the owner, demonstrating that the proposed mix design will achieve the required strength, durability, and performance requirements.</li> </ul> |
| (2) Prescription:<br>When the owner assumes responsibility for the concrete.   | <ul style="list-style-type: none"> <li>(a) mix proportions, including the quantities of any or all materials (i.e., admixtures, aggregates, cementing materials, and water) by mass per m<sup>3</sup> of concrete;</li> <li>(b) the range of air content;</li> <li>(c) the slump range;</li> <li>(d) use of a concrete quality plan, if required; and</li> <li>(e) other requirements.</li> </ul>  | <ul style="list-style-type: none"> <li>(a) plan the construction methods based on the owner's mix proportions and parameters;</li> <li>(b) obtain approval from the owner for any deviation from the specified mix design or parameters; and</li> <li>(c) identify to the owner any anticipated problems or deficiencies with the mix parameters related to construction.</li> </ul>  | <ul style="list-style-type: none"> <li>(a) provide verification that the plant, equipment, and all materials to be used in the concrete comply with the requirements of this Standard;</li> <li>(b) demonstrate that the concrete complies with the prescriptive criteria as supplied by the owner; and</li> <li>(c) identify to the contractor any anticipated problems or deficiencies with the mix parameters related to construction.</li> </ul>  |



**The owner shall specify**

- (a) required structural criteria including strength at age;
- (b) required durability criteria including class of exposure;
- (c) additional criteria for durability, volume stability, architectural requirements, sustainability, and any additional owner performance, pre-qualification or verification criteria;
- (d) quality management requirements (see [Annex J\\*](#));
- (e) whether the concrete supplier shall meet certification requirements of concrete industry certification programs;\* and
- (f) any other properties they may be required to meet the owner's performance requirements.

## Annex J Details: The owner/specifier is responsible for:

1. **Appointing a competent design authority** and implementing an appropriate QA process and management system (In most cases, this will be the specifier).
2. The Design authority then is responsible for :
  - **Establishing the performance criteria** based on the expected exposure conditions during placement and in service.
  - Preparing the technical specification that clearly states the performance criteria.
  - **Pre-qualification or verification criteria** quality management requirements.
  - **Conducting QA** and reviewing quality assurance reports to that the performance criteria have been met.
  - **Defining the relevant exposure classes** for each concrete element.
  - **Stating any other required concrete properties** to meet the desired performance.



## The supplier shall

- (a) certify that the plant, equipment, and all materials to be used in the concrete comply with the requirements of this Standard;
- (b) certify that the mix design satisfies the requirements of this Standard;
- (c) certify that production and delivery of concrete will meet the requirements of this Standard;
- (d) certify that the concrete complies with the performance criteria specified;
- (e) prepare and implement a quality control plan to ensure that the owner's and contractor's performance requirements will be met if required;
- (f) provide documentation verifying that the concrete supplier meets industry certification requirements, if specified;\* and
- (g) at the request of the owner, submit documentation to the satisfaction of the owner demonstrating that the proposed mix design will achieve the required strength, durability, and performance requirements.

The Concrete Supplier is not required to disclose the mix proportions.

The materials used have to meet the standards and performance requirements need to be demonstrated

# The Concrete Supplier shall...

1. **Certify** that the **concrete production plant, equipment, and all materials** to be used in the concrete comply with the specified requirements.
2. **Certify** that the **concrete mix design** satisfies the prequalification requirements of the performance standard
3. **Certify** that **production and delivery** of concrete meets the requirements of the performance standard.
4. **Prepare and implement a QC plan** to ensure that the owner's and contractor's performance requirements will be met.
5. **Provide documentation** verifying that they meet industry certification requirements, if required.
6. At the request of the owner, **submit documentation to the satisfaction of the owner** demonstrating that the proposed mixture design will achieve the required strength and durability performance requirements.

**The contractor shall**

- (a) work with the supplier to establish the concrete mix properties to meet performance criteria for plastic and hardened concrete, considering the contractor's criteria for construction and placement and the owner's performance criteria;
- (b) submit documentation demonstrating the owner's pre-qualification performance requirements have been met; and
- (c) prepare and implement a quality control plan to ensure that the owner's performance criteria will be met and submit documentation demonstrating the owner's performance requirements have been met.



# Annex J Details: The contractor is responsible for:

1. Procuring concrete and related materials and incorporating them into the structure in a manner that meets both the plastic and hardened performance requirements.
2. **Submitting documentation** demonstrating the owner's pre-qualification performance requirements have been met
3. **Preparing and implementing a QC plan** to ensure that the owner's performance criteria will be met and submit documentation demonstrating the owner's performance requirements have been met.
4. **Working with the supplier to meet establish concrete mixtures** to meet the performance criteria for plastic and hardened concrete, considering the contractor's criteria for placement so the final product meets the owner's performance criteria.
  1. This requires awareness of the performance test programme prior to bidding in order to allow for associated costs.
  2. Detailing in their bid how special performance requirements will be met.
  3. Being aware of handling, constructability, curing concrete and scheduling issues that influence the in-place concrete properties.
  4. Correcting any errors or deficiencies (non-conformance) immediately, notifying the owner of the corrective action taken.

# Contractor Quality Control Plan should include:

- (a) Organization charts, roles and responsibilities, and **ID of the person in charge of Quality management for the project** (this can include personnel for the supplier and subcontractor as well as the contractor);
- (b) **document management** and data retention process;
- (c) **concrete construction processes**, including placing, protection, finishing and curing;
- (d) **verification of concrete mixes** and submittal(s) process;
- (e) **non-conformance management process** including identification, reporting and procedure to correct and prevent reoccurrence;
- (f) **quality control testing**, reporting, and inspection plan;
- (g) **change management process** including a procedure to inform all parties of changes to the construction process or concrete mix design affecting performance and to indicate quality control adjustments to assess how performance criteria will still be met.



# Contractor responsibilities (regarding site storage of test specimens)

- To facilitate testing, the contractor shall provide and maintain, for the sole use of the testing agency, **adequate facilities for safe storage and proper curing of concrete test specimens** on the project site for the initial curing period.
- Adequate facilities shall include a protected and temperature-controlled designated area to comply with CSA A23.2-3C.

During initial curing period (20-36h), test specimens must be kept between 15-25°C and protected from drying.



# CSA A23.1 Thermal Control Plan Requirements

**The contractor shall submit to the owner for approval a thermal control plan** to demonstrate that the requirements for controlling and monitoring temperature will be achieved during the thermal control period, including the following information unless otherwise specified or approved by the owner:

- dimensions of mass placements;
- specified temperature limits;
- concrete mix design submittal;
- methodology used for thermal analysis and/or modelling;
- properties of the concrete;
- predicted adiabatic temperature rise of the concrete;
- concrete placing temperature considerations;
- calculated maximum concrete temperature;
- calculated maximum concrete temperature difference;
- ambient temperature and weather considerations;
- insulation and curing recommendations;
- temperature monitoring devices and locations;
- requirements to avoid thermal shock (24 h concrete surface temperature drop);
- criteria to terminate thermal control;
- recommendations to meet temperature limits;
- results from thermal analysis and/or modelling;
- possible corrective measures;
- relevant technical guidelines or references

# Annex J: Contractor & Concrete Supplier Joint Responsibilities

“Since in a typical construction project the custody of the concrete transfers from the supplier to the contractor while in its plastic state, a high degree of coordination is required between supplier and contractor to ensure that the final product meets the performance criteria and that the quality control processes are compatible and demonstrate compliance.”

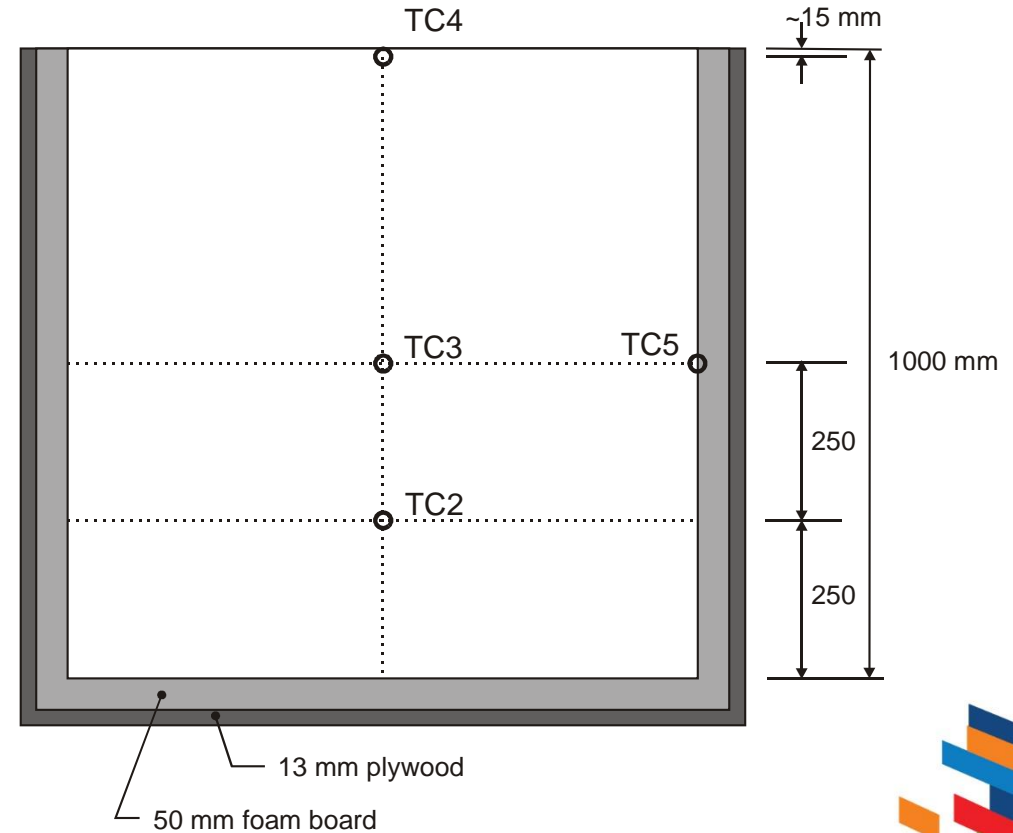


# Pre-Qualification Tests for Mass Concrete

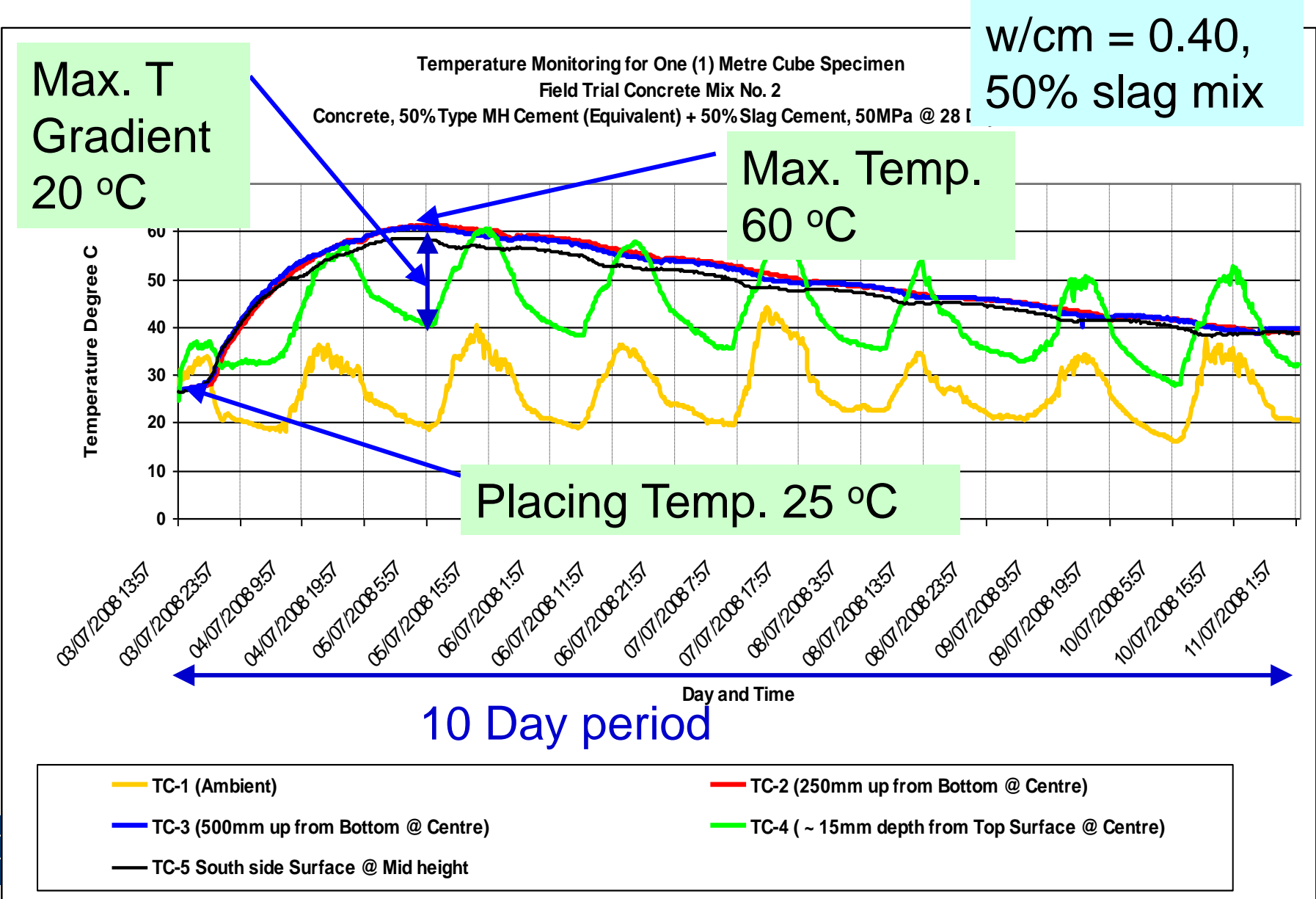
Concrete Suppliers can pre-qualify their Proposed Mixes using Monolith Tests



TC1 - Ambient



# Example 1m<sup>3</sup> Cube Trial Temperatures



# CSA Testing laboratory responsibilities

The testing laboratory shall be responsible for the following:

- a) **Laboratory, field personnel and equipment shall** meet the requirements of CSA A283 to the appropriate category, or other equivalent certification approved by the owner.
- b) All testing to the applicable test methods and standard practices of CSA A23.2,
- c) that reports are distributed and all related records are available for audit by the certification agency.



# Also, we need to state where performance is to be measured



|                  |                     |                              |                 |
|------------------|---------------------|------------------------------|-----------------|
| Prequalification | Identity Testing    |                              |                 |
|                  | Acceptance at Chute |                              |                 |
|                  |                     | Accept at Point of Placement |                 |
|                  |                     |                              | Accept in-place |



# Types of Testing

- 1. Pre-qualification:** To provide a mixture that when placed under defined conditions can meet the spec. (CSA A23.2-24C)
- 2. On-site QA/QC:** To document that,
  - a) materials supplied meet spec.
  - b) the concrete supplied is equivalent to that which was pre-qualified (**Identity Tests**),
  - c) pre-qualified placing practices are being followed. (**ie. test at each change of ownership**) (CSA A23.2-25C)
- 3. In-place:** Using NDT and/or tests on cores extracted on a statistical basis from the structure to ensure that the concrete + placement meet owner-defined performance levels (used by some agencies such as MTO).

# CSA A23.2-24C Mix Qualification Requirements

- These procedures specify the amount of testing to be done and the requirements for reporting on the conformance or non-conformance of products with specifications.
- Qualification testing is intended to assess the properties and characteristics of a proposed concrete mix design in advance of its use on a project, for the purpose of determining whether the proposed product complies with the requirements of this Standard, and whether it is acceptable to the owner.
- The qualification testing requirements for the concrete should be appropriate to the scope, size, and nature of the project.
- Optional test methods should be used when appropriate to address significant performance requirements based on the applicable exposure conditions or size and scope of project.

# CSA A23.2-24C Submittals (Performance Option)

- The project specifications shall identify **submittal requirements that are appropriate to the scope, size, and nature of the project.**
- **The contractor shall** submit documentation for qualification demonstrating that the owner's performance requirements will be met.
- **The concrete supplier shall** submit the following documentation:
  - Submit documentation to the satisfaction of the owner, demonstrating that the proposed mix design will achieve the required strength, durability, and performance requirements.
- **Note:** *Prequalification test results may be supplied using similar materials and mix designs to those proposed for the project.*

# The extent & types of Qualification tests depends on the Owner's specification requirements & exposure class

- Qualification of concrete shall include the following as applicable in accordance with the project specifications and the specified exposure class:
- compressive strength;
- slump tests, or slump flow tests;
- plastic air content;
- Hardened air void system parameters where concrete is subject to the exposures requiring Category 1 air entrainment;
- chloride ion penetrability for steel reinforced or pre-stressed concrete;
- density of plastic concrete measured, if specified;
- flexural strength of concrete;
- linear shrinkage;
- salt scaling resistance, where limits are specified in the contract documents; and
- chloride ion content.

## *Standard Practice for sampling, testing, and inspection of concrete for acceptance purposes*

- **Quality control**

### 8.1 Owner's responsibility

- The owner shall be responsible for **quality assurance** processes to verify that the requirements for concrete are met.

### 8.2 Concrete supplier's responsibility

- The concrete supplier shall be responsible for **quality control** processes to ensure and verify that the requirements for concrete as delivered are met.

Again, emphasizing responsibilities

## CSA A23.2-25C

# ***Standard Practice for sampling, testing, and inspection of concrete for acceptance purposes***

### Some points of interest:

- Where there is more than one set of test results representing the same concrete sample available from multiple independent testing laboratories certified in accordance with the requirements of CSA A23.1, **all test results shall be considered by the owner** unless there is a defined referee testing program in place.
- When the owner elects to assess the quality of concrete at a location other than the point of discharge from the delivery equipment, the owner shall state in the project specification the point at which the samples shall be taken.

# Summary

- Performance Specifications can result in better concrete construction and durability provided that all parties are on-board.
- Performance specifications allow for innovation in the supply of concrete by providing flexibility in materials supply and concrete proportions.
- This can be used to allow use of **more environmentally friendly** concrete materials and mix proportions.
- However, performance means more than acceptance of concrete at the end of the truck chute.
- To an owner it means in-place performance of the structure, so the concrete producer and contractor have to work as a team to meet the Owner's specifications.
- The risks & responsibilities are different than in Prescriptive specifications, so there is a learning curve.

