CONTENT

RMCAO

TECHNICAL SPECIFICATIONS

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THE Power of Concrete

Casting Concrete Test Cylinders

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CSA A23.2-3C

The material properties of concrete can only be properly evaluated if test specimens are made and cured according to CSA standards. Concrete compression cylinders are typically made to evaluate the compressive strength of the concrete. If curing conditions, methods of sampling and methods of casting are allowed to vary, the resulting material evaluations are worthless because one can seldom determine whether a low strength is due to poor quality concrete or poor testing practices. For reliable test results, the following CSA test procedures must be followed:

1. USE ONLY NON-ABSORPTIVE MOULDS

Metal, plastic, 100 x 200 mm or 150 x 300 mm cylinder moulds are used for casting concrete test specimens in the field. Before filling, they should be placed on a smooth, firm, level surface. A single strength test is defined as the average strength of 2 standard test specimens.

2. SAMPLING

Obtain a representative grab sample from between the 10% and 90% points of discharge. The minimum sample size shall be 20 L for 100 x 200 mm cylinders and 30 L for 150 x 300 mm cylinders.

3. CONCRETE AT DIFFERENT SLUMP LEVELS REQUIRE DIFFERENT METHODS OF CONSOLIDATION

The methods of consolidation are rodding and external or internal vibration. Rod concretes with a slump $>$ 40 mm. Vibrate concretes with a slump $\leq$ 40 mm.

Photo courtesy of CAC

A. RODDING CONCRETE

100 mm diameter – moulds should be filled in 3 equal layers and each layer rodded uniformly 20 times with a 10 mm diameter x 450 - 600 mm long hemi-spherically tipped steel rod.

150 mm diameter – moulds should be filled in 3 equal layers and each layer rodded uniformly 25 times with a 16 mm diameter x 450 - 600 mm long hemi-spherically tipped steel rod.

The strokes shall be distributed uniformly over the cross-section of the mould. The bottom layer shall be rodded throughout its depth. For each upper layer, the rod shall penetrate about 25 mm into the underlying layer. If voids are left by the rod, the sides of the mould should be tapped to close voids before adding the next layer of material.

Photo courtesy of CAC

B. VIBRATING CONCRETE

- Fill moulds in 2 equal layers and vibrate each layer until the concrete becomes smooth and there is no further egress of entrapped air bubbles.
- Care shall be taken that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen.
- The procedure of external and internal vibration is clearly set out in CSA A23.2 - 3C Clause 4.4.

4. LET CYLINDERS CURE MINIMUM 20 HOURS IN 20 ±5°C TEMPERATURES

Cylinders should be placed on a rigid horizontal surface free from vibration and left undisturbed until they have hardened enough to withstand handling – minimum 20 hours after casting. Test cylinders should be placed in a controlled environment, such as a curing box, during this period. Tops should be covered with a nonabsorptive, nonreactive plate or placed in an impervious plastic bag to prevent loss of moisture. **The temperature should be 20 ±5°C WHERE CYLINDERS ARE STORED and records of the maximum and minimum temperatures kept.**

Photo courtesy of CAC

5. CURE AND HANDLE CYLINDERS WITH CARE

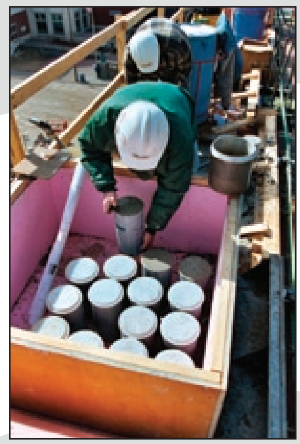

Photo courtesy of CAC

After setting for a minimum 20 hours, cylinders should be moved to a laboratory for standard curing, taking care to ensure that a temperature of 20 ±5°C is maintained at all times and during transportation to the laboratory. Careful handling is necessary since cylinders which are allowed to rattle around in a box, or the back of a car, or pickup, can suffer considerable damage. Use sawdust or similar materials for cushioning.

6. DEMOULDING TIME OF TEST SPECIMENS

Test specimens to be used as the basis of acceptance of the concrete shall be removed from the moulds at the end of 28 ± 8 hours and stored in a moist condition at a temperature of 23 ±2°C until the time of testing. Demoulding time may be extended to a maximum of 76 h for cylinders representing a specified compressive strength of < 35 MPa.

References:

1 CSA A23.2-04 Methods of Test and Standard Practices for Concrete.

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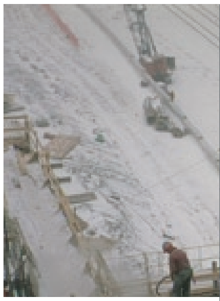

Cold Weather Concreting

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Weather conditions can have a dramatic effect on both the setting time and concrete placing, finishing and protection systems that must be followed for proper concrete placement. Cold weather concreting conditions are typically defined as:

- When the air temperature is ≤ 5°C.
- Or when there is a probability that the temperature may fall below 5°C within 24 hours of placing the concrete.

Because the hydration process is a chemical reaction it is strongly affected by ambient air and subgrade/formwork temperatures. At low temperatures concrete gains strength and sets very slowly and must be adequately protected from freezing and thawing. Concrete that is allowed to freeze while in its plastic state can have its potential strength reduced by more than 50% and its durability properties will be dramatically reduced. Concrete must achieve at least 3.5 MPa before it is frozen and should obtain at least 20 MPa before it is exposed to multiple freeze/thaw cycles.

General procedures for cold weather concreting include:

- Removing all ice and snow from the subgrade or formwork.
- Supplying the necessary supplemental heat required to ensure that forms, subgrades, and reinforcing steel is maintained a minimum temperature of 5°C well prior to the concrete placement.
- Ordering concrete with a temperature between 10°C – 25°C.

Photo courtesy of CAC

Photo courtesy of Lafarge Camada Inc.

- Concrete should be ordered using the lowest practical water slump since this will reduce bleeding and setting times. Chemical admixture can still be used to improve the workability of the concrete.
- Chemical admixtures and mix design modifications can be used to offset the slower setting times and strength gain of concrete during cold weather conditions. Considerations should be given to ordering concrete that will obtain higher early strengths.
- Concrete temperature must be maintained at a minimum of 10°C for the full curing period.
- The surface of the concrete should not be allowed to dry out while it is still plastic since this may cause plastic shrinkage cracking. The longer set times encountered during cold weather combined with the effects of hot dry air from heaters being blown along the top surface of the concrete significantly increase this risk.
- Wet curing methods are typically not recommended during cold weather conditions since the concrete will not have a sufficient time period to air dry before the first freeze/thaw cycle.
- The possibility of thermal cracking must be considered when the heating supplied during the curing period is going to be suspended. Concrete should not be allowed to cool at a rate outside the limits listed in CSA A23.1 Table 21.

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CSA A23.1 – TABLE 21

Maximum permissible temperature differential between concrete surface and ambient (wind up to 25km/h)

(see Clauses 7.4.2.3 and 7.4.2.5.3.4)

	Maximum permissible temperature differential, °C				
	Length to height ratio of structural elements*				
Thickness of concrete, m	0†	3	5	7	20 or more
< 0.3	29	22	19	17	12
0.6	22	18	16	15	12
0.9	18	16	15	14	12
1.2	17	15	14	13	12
> 1.5	16	14	13	13	12

** Length shall be the longer restrained dimension and the height shall be considered the unrestrained dimension.*
† Very high, narrow structural elements such as columns.

Special care should be taken with concrete test specimens used for the acceptance of the concrete. The initial test specimens shall be stored in a controlled environment that maintains the temperature at 20 ± 5°C as per CSA A23.1/.2 requirements.

Photo courtesy of CAC

Caution regarding the use of portable gas fired heaters:

Photo courtesy of CAC

Plastic concrete exposed to a carbon dioxide source (CO_2) during the concrete placing, finishing and curing period will develop a soft, chalky, carbonated surface (known as dusting). Carbon Dioxide is an odourless and colourless gas that is heavier than air and is produced by all forms of combustion. Typical sources include: open flame heaters (stacks must be vented to outside), and internal combustion engines (e.g. on trucks, power trowels, concrete buggies, etc.). Precautions **must** therefore be taken to properly vent the placement area.

References:

1 CSA A23.1-04 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International

2 Ontario Building Code – 1997, Ontario Ministry of Municipal Affairs and Housing – Housing Development and Buildings Branch

3 Design and Control of Concrete Mixtures – 7th Canadian Edition, Cement Association of Canada

4 Concrete in Practice #27 – Cold Weather Concreting, National Ready Mixed Concrete Association

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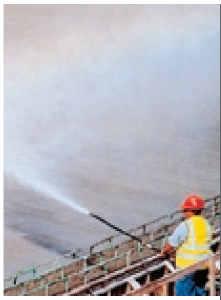

Hot Weather Concrete

3

Weather conditions can have a dramatic effect on both the setting time and concrete placing, finishing and protection systems that must be followed for proper concrete placement. Hot weather concreting conditions typically include:

- High ambient air temperatures (≥ 28°C)
- Low relative humidity conditions
- High wind speeds
- Solar radiation or heat gain

These conditions can result in the following challenges for the concrete contractor:

- Increased concrete water demand
- Accelerated concrete slump loss
- Increased rate of setting leading to placing and finishing difficulties
- Increased tendency for plastic shrinkage cracking
- Increased concrete temperature resulting in lower ultimate strength
- Increased potential for thermal cracking

The first step that must be taken is to identify when hot weather concreting conditions may apply and modify the normal concrete placing and finishing procedures accordingly. Possible steps that may be taken include:

Preparation

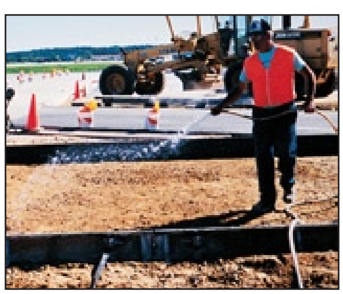

Photo courtesy of CAC

ACI recommendations regarding the pre-wetting of the subgrade have recently changed so that this procedure is not typically recommended. The only exception is during hot weather conditions were plastic shrinkage cracking may be an issue. The subgrade should be pre-wetted and forms and reinforcing steel should be dampened prior to concrete placing (there should be no standing water). The purpose of these actions is to prevent the absorption of water from the concrete into the subgrade.

Photo courtesy of CAC

Ordering

Inform the ready mixed concrete producer of your placing schedule and whether a chemical retarder will be required. For exposed flatwork the use of retarding admixtures or supplementary cementing materials should be discussed with the concrete producer. In extreme cases the concrete temperature may also be lowered by using chilled water, ice or liquid nitrogen.

Slump

A concrete consistency (slump) which allows for rapid placement and consolidation should be considered. Chemical admixtures such as super-plasticizers can dramatically improve the concrete slump and reduce placement times.

Placing

After the concrete is properly mixed ensure that it is discharged as soon as possible. Consider the use of large crews to accelerate placement rates.

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Finishing

Photo courtesy of CAC

In cases where protection against rapid evaporation of water from the concrete surface is a concern, (Figure 1) consider the use of one or more of the following actions:

- Erect sunshades and wind breaks
- Cover the surface with white polyethylene sheets
- Apply fog spray
- Place and finish at night or early morning
- Apply temporary evaporation retarder after the screeding operation

Curing

Curing should be started as soon as the concrete has set enough to avoid any surface damage. Concrete should be cured for at least 7 consecutive days after placing. Ensure that the concrete is kept moist throughout the curing process (see technical bulletin on curing options).

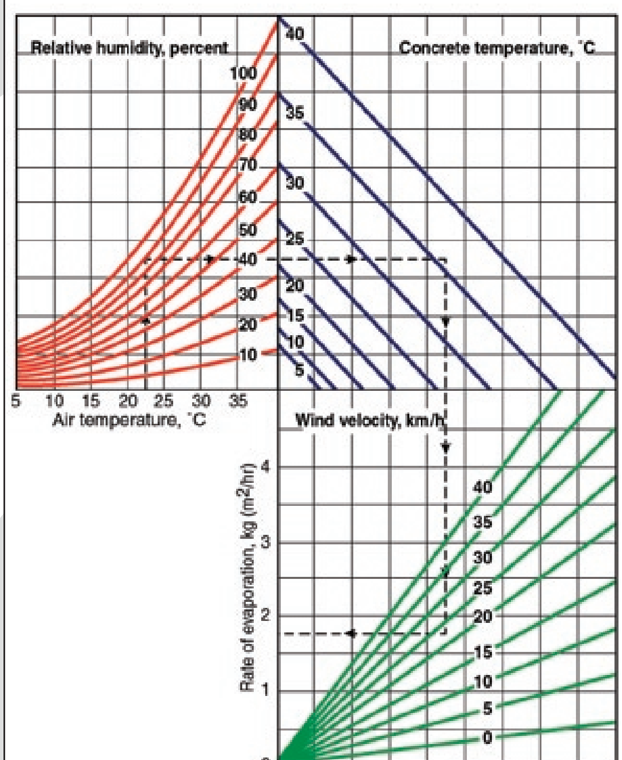
Testing

To avoid inaccurate strength test results, the initial test specimens shall be stored in a controlled environment that maintains the temperature at 20 ± 5°C as per CSA A23.1/.2 requirements. Concrete test cylinders that exceed these temperature requirements typically exhibit much lower 28 day strengths.

FIGURE 1

Estimation of rate of evaporation of moisture from a concrete surface

(See Clause 7.4.2.2.)



Note: Adapted (with metric values) from PCA EB101.05T. Additional information can be obtained from Berhane, 1984, and discussions of this article in ACI Materials Journal 82 (1985). Futher information and background can be obtained from Uno, 1998.

Photo courtesy of CAC

To use this chart:
1. Enter with air temperature, move *up* to relative humidity.
2. Move *right* to concrete temperature.
3. Move *down* to wind velocity.
4. Move *left*; read approx. rate of evaporation.

References:

1 CSA A23.1-04 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International

2 Design and Control of Concrete Mixtures – 7th Canadian Edition, Cement Association of Canada

3 Concrete in Practice #12 – Hot Weather Concreting, National Ready Mixed Concrete Association

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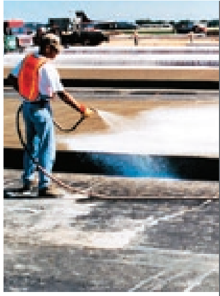

TECHNICAL SPECIFICATIONS

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Curing Concrete

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Curing is defined as **"maintenance of a satisfactory moisture content and temperature in the concrete for a period of time immediately following placing and finishing so that the desired properties may develop."** Early curing is critical when the concrete will be exposed to harsh Canadian weather conditions since it dramatically affects the permeability and durability of the concrete. In some instances curing must be initiated even before the finishing operations are complete to provide the necessary concrete properties.

Since the strength and durability properties of concrete are set by the chemical reactions of the various components during the hydration process, there are three key factors to proper curing.

- **Moisture** – Having sufficient moisture to ensure the hydration process continues
- **Temperature** – Maintaining a sufficient temperature (≥10°C) to ensure that the chemical reaction continues
- **Time** – Maintaining both the moisture and temperature requirements for a minimum period of time (3 – 7 days – See CSA A23.1 – Table 20) to ensure that the durability properties fully develop. Curing needs to be initiated as soon as the finishing operations are complete and the surface will not be damaged by the curing operation.

General Notes Regarding Concrete Curing:

1. Alternating cycles of wetting and drying during the curing process is extremely harmful to the concrete surface and may result in surface crazing and cracking. **This should be avoided at all costs.**
2. A 28 day air drying period is recommended immediately following the 28 day curing period to provide the necessary freeze/thaw resistance for the concrete. Curing methods that result in fully saturated concrete, which will be exposed to freeze/thaw cycles once the curing period is over, may result in premature deterioration of the concrete (even if the concrete is properly air entrained).
3. Concrete with low W/CM ratios (≤ 0.40) may not have sufficient free moisture in the mix to allow for the use of **"moisture loss prevention"** curing methods. This situation should be reviewed prior to the start of the project.

Curing of concrete can be completed by two basic methods:

- Preventing the loss of moisture from the concrete
- Keeping the exposed surface continuously wet

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Photo courtesy of RMCAO

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Possible curing methods are outlined in the following table:

Moisture Loss Prevention	Supplying Supplemental Moisture
Curing Compounds • Form a membrane over the top surface of the concrete preventing moisture loss • Must be applied at the manufacturers suggested application rate • Should be applied in two applications with the second being at right angles to the first to ensure uniform coverage • Should be applied as soon as the concrete surface is finished and when there is no free water on the surface • Curing compounds can effect the "bond" of some floor coverings • Confirm that this curing method is suitable for the final floor covering application	**Water Ponding** • Flooding of the concrete surface to provide both moisture and a uniform curing temperature • Curing water should not be more than 12°C cooler than the concrete temperature to avoid the possibility of thermal cracking • The water must cover the entire concrete surface **Water Sprinkling** • Spraying water over the concrete surface. The entire concrete surface must be wet for this method to be effective • The concrete surface must have sufficient strength to avoid damaging the surface • Excess water will run off the concrete and must be drained away • This protection method can be adversely affected by high winds which prevent proper curing on the "upwind" side
Plastic Sheeting • Ensure that the plastic sheeting covers 100% of the concrete surface and that it is adequately sealed at the edges to prevent moisture loss • Select the appropriate colour (white, black, or clear) of the plastic based upon the ambient air conditions • If uniform colour is a requirement for the project ensure that the plastic is not placed directly on the concrete surface • Ensure that plastic sheeting is not damaged by subsequent construction activities during the curing period	**Wet Burlap** • Pre-soaked burlap is applied to the concrete surface and is covered with plastic to prevent moisture loss or water is reapplied as necessary to prevent the material from drying out • Burlap should be rinsed prior to its first use to avoid possible staining • Materials utilizing both geotextile fabric and plastic top coatings can be reused throughout the project
Leaving Formwork In Place • This system is most effective for vertical elements (walls, columns, beams, etc). Care must be taken to also protect the top surface of the concrete appropriately • "Breaking" or "Releasing" the formwork dramatically reduces the effectiveness of this curing method since air flow is now possible between the concrete and the formwork • If uniform colour is an issue then a uniform curing time and temperature must also be maintained and form removal scheduled accordingly	**Wet Sand** • Wet loose material such as sand can be used to cure concrete slabs and footings • The sand thickness must be sufficient to prevent moisture loss at the concrete surface or the sand must be wetted throughout the curing period

CSA A23.1 – TABLE 20

Allowable curing regimes

(see Clause 4.1.1.1.1, 7.4.1.1, 7.4.1.7.1, and Table 2)

Curing Type	Name	Description
1	Basic	3 d at ≥ 10°C or for a time necessary to attain 40% of the specified strength.
2	Additional	7 d at ≥ 10°C and for a time necessary to attain 70% of the specified strength. When using silica fume concrete, additional curing procedures shall be used. See Annex I, Clause 1.3.13.
3	Extended	A wet-curing period of 7 d. The curing types allowed are ponding, continuous sprinkling, absorptive mat or fabric kept continuously wet.

References:

1 CSA A23.1-04 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International

2 Ontario Building Code – 1997, Ontario Ministry of Municipal Affairs and Housing – Housing Development and Buildings Branch

3 Design and Control of Concrete Mixtures – 7th Canadian Edition, Cement Association of Canada

4 Concrete in Practice #11 – Curing In-Place Concrete, National Ready Mixed Concrete Association

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Concrete Exposure Classes

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Determination of the minimum concrete performance properties is based upon identifying the following key requirements:

- **Applicable Exposure Conditions** – The designer must assess the environmental conditions that the concrete will be exposed to during its service life. Direct input is also required from the Owner regarding possible future uses since they can significantly affect the exposure class selection
- **Structural Requirements** – The designer must determine the minimum concrete properties required to meet the applicable loading conditions
- **Architectural Requirements** – The designer must consider the effects of selecting various architectural finishes on concrete material properties.
- **Minimum Durability Requirements** – Based upon the designer's assessment of the exposure conditions, the CSA A23.1 standard sets minimum concrete properties.

In cases where these various factors result in differing material properties, the designer must select the most stringent requirement as the minimum concrete performance requirement.

CSA A23.1-04 – Concrete Materials and Methods of Concrete Construction, Tables 1 – 4 outline the minimum durability requirements.

Photo courtesy of OCA

Photo courtesy of RMCAO

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CSA A23.1 – TABLE 1

Definitions of C, F, N, A, and S exposure classes

(See Clauses 4.1.1.1.1, 4.1.1.5, 4.4.4.1.1.1, 4.4.4.1.1.2, 6.6.7.5.1, 8.4.1.2 and Tables 2 and 12.)

C-XL	Structurally reinforced concrete exposed to chlorides or other severe environments with or without freezing and thawing conditions, with higher durability performance expectations than the C-1, A-1 or S-1 classes.
C-1	Structurally reinforced concrete exposed to chlorides with or without freezing and thawing conditions. Examples: bridge decks, parking decks and ramps, portions of marine structures located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools.
C-2	Non-structurally reinforced (i.e. plain) concrete exposed to chlorides and freezing and thawing. Examples: garage floors, porches, steps, pavements, sidewalks, curbs, and gutters.
C-3	Continuously submerged concrete exposed to chlorides but not to freezing and thawing. Examples: underwater portions of marine structures.
C-4	Non-structurally reinforced concrete exposed to chlorides but not to freezing and thawing. Examples: underground parking slabs on grade.
F-1	Concrete exposed to freezing and thawing in a saturated condition but not to chlorides. Examples: pool decks, patios, tennis courts, freshwater pools, and freshwater control structures.
F-2	Concrete in an unsaturated condition exposed to freezing and thawing but not to chlorides. Examples: exterior walls and columns.
N	Concrete not exposed to chlorides nor to freezing and thawing. Examples: footings and interior slabs, walls and columns.
A-1	Structurally reinforced concrete exposed to severe manure and/or silage gases, with or without freeze-thaw exposure. Concrete exposed to the vapour above municipal sewage or industrial effluent, where hydrogen sulphide gas may be generated. Examples: reinforced beams, slabs and columns over manure pits and silos, canals, pig slats, access holes, enclosed chambers, and pipes that are partially filled with effluents.
A-2	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure. Examples: reinforced walls in exterior manure tanks, silos and feed bunkers, exterior slabs.
A-3	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure in a continuously submerged condition. Concrete continuously submerged in municipal or industrial effluents. Examples: interior gutter walls, beams, slabs and columns, sewage pipes that are continuously full (e.g., force mains), and submerged portions of sewage treatment structures.
A-4	Non-structurally-reinforced concrete exposed to moderate manure and/or silage gases and liquids, without freeze-thaw exposure. Examples: interior slabs on grade.
S-1	Concrete subjected to very severe sulphate exposure (Tables 2 and 3).
S-2	Concrete subjected to severe sulphate exposure (Tables 2 and 3).
S-3	Concrete subjected to moderate sulphate exposure (Tables 2 and 3).

Notes:

(1) *"C" classes pertain to chloride exposure.*
(2) *"F" classes pertain to freezing and thawing exposure without chlorides.*
(3) *"N" class is exposed to neither chlorides nor freezing and thawing.*
(4) *"A" class pertains to agricultural, municipal or industrial projects exposed to human or animal wastes.*
(5) *All classes of concrete, exposed to sulphates, shall comply with the minimum requirements of of "S" class noted in Tables 2 and 3.*

CSA A23.1 – TABLE 2

Requirements for C, F, N, R, S and A classes of exposure

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.2.1, 4.3.1, 7.4.1.1, 8.8.3, and 8.8.6.1, and Table 1.)

Requirements for specifying concrete

Class of exposure*	Maximum water-to-cementing materials ratio†	Minimum specified compressive strength (MPa) and age (d) at test†	Air content category as per Table 4	Curing type (see Table 20)			Chloride ion penetrability test requirements and age at test‡
				Normal concrete	HVSCM 1	HVSCM 2	
C-XL	0.37	50 within 56 d	1 or 2§	3	3	3	< 1,000 coulombs within 56 d
C-1 or A-1	0.40	35 at 28 d	1 or 2§	2	3	2	< 1,500 coulombs within 56 d
C-2 or A-2	0.45	32 at 28 d	1	2	2	2	
C-3 or A-3	0.50	30 at 28 d	2	1	2	2	
C-4** or A-4	0.55	25 at 28 d	2	1	2	2	
F-1	0.50	30 at 28 d	1	2	3	2	
F-2	0.55	25 at 28 d	2††	1	2	2	
N‡‡	For structural design	For structural design	None	1	2	2	
S-1	0.40	35 at 56 d	2	2	3	2	
S-2	0.45	32 at 56 d	2	2	3	2	
S-3	0.50	30 at 56 d	2	1	2	2	

** See Table 1 for description of classes of exposure.*

† The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementing materials ratio. The water-to-cementing materials ratio shall not be exceeded for a given class of exposure.

‡ In accordance with ASTM C 1202. An age different from that indicated may be specified by the owner. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, but without calcium nitrite, shall be prequalified to meet the requirements for the permeability index in his Table.

§ Use Category 1 for concrete exposed to freezing and thawing. Use air content Category 2 for concrete not exposed to freezing and thawing.

*** For class of exposure C-4, the requirement for air entrainment should be waived when a steel trowelled finish is required. The addition of supplementary cementing materials may be used to provide reduced permeability in the long term, if that is required.*

†† Interior ice rink slabs and freezer slabs with a steel trowelled finish have been found to perform satisfactory without entrained air.

‡‡ To allow proper finishing and wear resistance, Type N concrete intended for use in an industrial concrete floor with a trowelled surface exposed to wear shall have a minimum cementing materials content of 265 kg/m^3.

CSA A23.1 – TABLE 3

Additional requirements for concrete subjected to sulphate attack*

(See Clauses 4.1.1.1.1, 4.1.1.6.2, 4.1.1.6.3, 8.4.1.2 and Tables 1.)

Class of exposure*	Degree of exposure	Water soluble sulphate (SO_4)† in soil sample, %	Sulphate (SO_4) in groundwater sample, mg/L‡	Water soluble sulphate (SO_4) in recycled aggregate sample, % §	Cementing materials to be used**
S-1	Very severe	> 2.0	> 10,000	> 2.0	HS or HSb
S-2	Severe	0.20 – 2.0	1,500 – 10,000	0.60 – 2.0	HS or HSb
S-3	Moderate	0.10 – 0.20	150 – 1,500	0.20 – 0.60	MS, MSb, LH, HS, or HSb

* *For sea water exposure, see Clause 4.1.1.5.*
† *As per CSA A23.2-3B.*
‡ *As per CSA A23.2-2B.*
§ *Cementing material combinations with equivalent performance maybe used (see Clauses 4.2.1.2, 4.2.1.3, and 4.2.1.4). Type HS cement shall not be used in reinforced concrete exposed to both chlorides and sulphates. Refer to Clause 4.1.1.3.*

CSA A23.1 – TABLE 4

Requirements for the air content categories

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.2.3.2.2., 4.3.1.1, 4.3.3.1, 4.3.3.2, 4.4.4.1.1.1, and Tables 2)

	Range in air content* for concrete with indicated nominal maximum sizes of coarse aggregate, %		
Air content category	10 mm	14 – 20 mm	28 – 40 mm
1†	6 – 9	5 – 8	4 – 7
2	5 – 8	4 – 7	3 – 6

* *At the point of discharge from the delivery equipment, unless otherwise specified.*
† *For hardened concrete, see Clause 4.3.3.2.*

Notes:
(1) *The above difference in air contents has been established based upon the difference in mortar fraction volume required for specific coarse aggregate sizes.*
(2) *Air contents measured after pumping or slip forming may be significantly lower than those measured at the end of the chute.*

References:
1 CSA A23.1-04 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International

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TECHNICAL SPECIFICATIONS

Proper Field Testing Of Ready Mixed Concrete

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Summaries of Canadian Standards Association CSA A23.2-04 "Methods of Test and Standard Practices for Concrete"

- **A23.2-1C – Sampling**
- **A23.2-3C – Cylinders**
- **A23.2-4C – Air Test**
- **A23.2-5C – Slump of Concrete**

Prepared for the Test Laboratories, Contractors, Owners, Architects, Engineers, Government Agencies, and Concrete Producers

Sampling of Plastic Concrete

A23.2-1C

General

- avoid segregation
- complete diversion of concrete from chute
- between 10 and 90% of load

Sampling for Cylinders, etc.

- one grab sample

Sampling for Uniformity

- three samples, widely separated

Sample Size - Strength, Uniformity

- For three 100 x 200 mm cylinders = minimum 20 L each
- For three 150 x 300 mm cylinders = minimum 30 L each
- complete remix prior to test

Protection

- protect sample from sun, wind, and other sources of evaporation or contamination

Making and Curing of Concrete Compression and Flexural Specimens

A23.2-3C

Time Constraint

- complete within 20 min after sampling

Place of Moulding

- near as practicable to storage and immediately placed there

Cover

- immediately covered to prevent moisture loss

Rodding

- 10 mm diam. rod for 100 mm cylinders
- 20 x per 3 layers
- 16 mm diam. rod for 150 mm cylinders
- 25 x per 3 layers

Consolidation

- sides of mould tapped to close voids

Curing

- rigid horizontal surface
- cylinders stored in controlled environment that maintains temperature at 20 ± 5°C
- cover cylinders
- record maximum and minimum temperatures within curing enclosure

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Demoulding

- normal 28 ± 8 hrs
- extended to maximum 76 hrs for concrete <35 MPa provided that:
  - stored in controlled environment that maintains temperature at 20 ± 5°C
  - cover cylinders
  - record maximum and minimum temperatures

Transport

- after proper time with protection

Air Content of Plastic Concrete by the Pressure Method

A23.2-4C

Time Constraint

- complete within 10 min after sampling

Calibration and Operation of Air Meter

- as per manufacturers' specifications

Rodding

- 25 x per 3 layers normal

Consolidation

- Tapped smartly 10 times per layer

Strikeoff, Cleaning, Measuring

- ensure a complete seal and prevent leakage

Air Content

- measure within the nearest 0.1%

Photo courtesy of RMCAO

Slump of Concrete

A23.2-5C

Time Constraint

- complete within 10 min after sampling

Location

- flat, moist, non-absorbent (rigid) surface

Filling

- 3 layers, 1/3 by volume each

Rodding

- 25 x per 3 layers
- 16 mm diam. rod

Consolidation

- NONE ALLOWED

Cone Lift/Removal

- approximately 5 x by steady straight upward lift

Slump

- record in millimetres to nearest 5 mm
- middle of original concrete specimen

FIELD TESTING CERTIFICATION

To comply to CSA A23.1/.2, all field testing personnel shall be certified.

A **CSA or ACI certificate** clearly stating name of individual, certified company of employment, date of expiry, and the tests for which the individual is certified shall identify all field test personnel.

IMPORTANT NOTE:

*Concrete tests not sampled, made, cured and handled in accordance to CSA A23.1/.2 shall not be considered valid and **will not be accepted by the Ready Mixed Concrete Producer.***

If there are any questions, or any occurrences of improper field-testing of concrete, please contact your Concrete Supplier or the Ready Mixed Concrete Association of Ontario.

Distribution of Cylinder Reports as per CSA A23.1 Clause 4.4.1.4.

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TECHNICAL SPECIFICATIONS

Proper Concrete Jointing Details to Control Random Cracking

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Shrinkage is an unavoidable fact of concrete construction. The key to a successful concrete project is understanding how to minimize shrinkage and knowing what steps to take to avoid random concrete cracking.

The primary factors that result in concrete shrinkage and/or cracking include:

- Settlement of the sub-grade
- Chemical shrinkage of the concrete
- Temperature and moisture changes in the concrete
- Application of loads to the concrete surface
- Restraint of concrete movement during either expansion or contraction.

The actual amount of concrete shrinkage is governed by:

- The concrete's raw constituents
- The unit water content of the mix
- The drying conditions that the concrete is exposed to
- The size and shape of the concrete element.

Once these facts are known, the designer and contractor can properly address concrete shrinkage by selecting the appropriate concrete thickness and layout, installing the necessary concrete jointing systems and utilizing the correct amount of reinforcement in suitable locations.

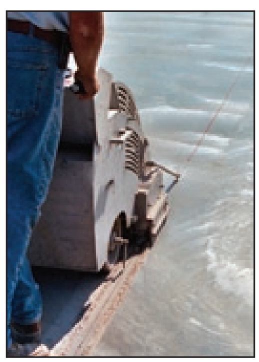

Photo courtesy of CAC

Methods to minimize the volume change of concrete and reduce internal stresses from a mix design standpoint include:

- Lowering the unit water content of the concrete as much as practical
- Using the largest practical size of coarse aggregate in order to minimize the paste content of the mix
- Utilizing well graded aggregate blends which exhibit low shrinkage
- Minimizing the water demand of the concrete by utilizing supplementary cementing materials
- Avoid admixtures that increase drying shrinkage (i.e. calcium chloride based accelerators).

Basics of Unreinforced Concrete Slab-on-Grade Construction

Photo courtesy of CAC

As stated previously, concrete shrinks in all directions as it cures. Whether the concrete will crack due to material shrinkage alone is dependent on the shape of the concrete, the thickness of the concrete and the restraint supplied by subgrade or adjacent elements. If the concrete is free to move then no stresses are created and the concrete doesn't crack. To avoid random concrete cracking we utilize a system of joints (isolation, contraction & construction) to force the concrete cracking to follow specific lines (See photo above).

The basic rules for layout of these joints are as follows:

- The maximum joint spacing should not exceed 24 to 36 times the thickness of the slab
- The resulting panels created by these joints should be as square as possible. The length/width ratio of the panels should never exceed 1.5
- Joint depths should be at least ¼ the depth of the slab
- Contraction joints should be located at all "re-entrant" corners (corners with angles greater than 90°) to prevent radial cracking
- "T" intersections of contraction joints should be avoided since the random cracks will tend to continue through into the next slab.

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The basic jointing systems are as follows:

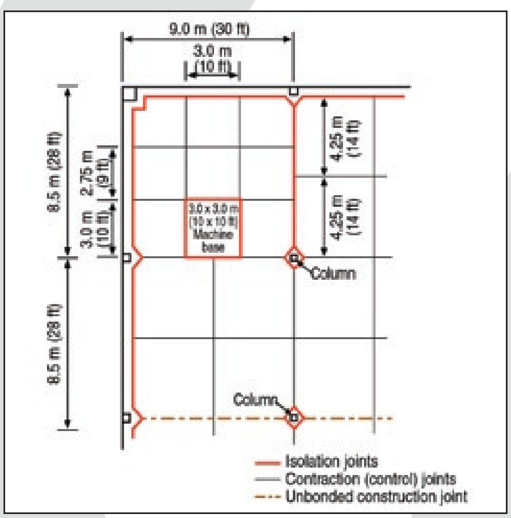
Isolation Joints: Joints that permit both horizontal and vertical movement between the slab and the adjacent concrete (see diagram 1). The purpose of this joint is to completely separate the two concrete elements (since they may move independently of each other) and to provide space for both expansion and contraction of the concrete. These joints are typically 13 mm in thickness and are constructed of a compressible material.

Contraction Joints: Joints that permit horizontal movement of the slab and induce controlled cracking at preselected locations (see diagram 2). These joints are typically created by grooving the concrete while it is still in the plastic state or cutting the concrete in its hardened state once it has obtained sufficient strength (typically 4 – 12 hours after placement).

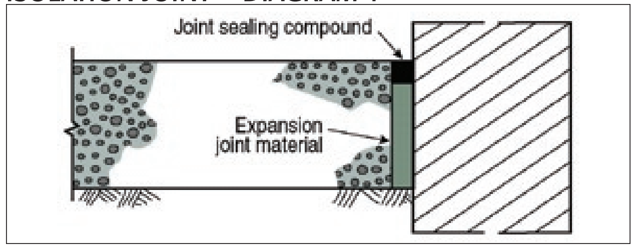
Construction Joints: Joints that are stopping places in the process of construction (see diagram 3). The person designing the joint layout has the option with construction joints to have them act as a contraction joint and allow horizontal movement only (diagram 3-b) or to create a fully bonded joint with deformed rebar and not permit either horizontal or vertical movement (diagram 3-c).

Proper jointing layout is performed before the concrete is placed by utilizing the basic rules above to determine the maximum joint spacing and then reviewing the plan view of the project to determine the proper locations of the three basic jointing types (see below). Concrete placement should never occur until a proper joint layout drawing has been prepared, reviewed and approved.

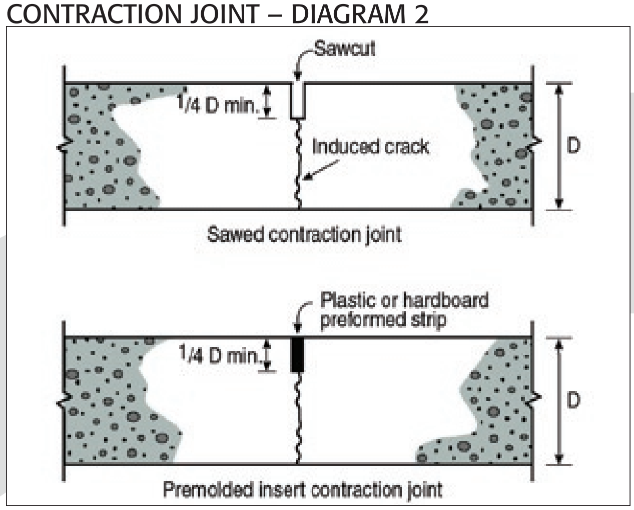
TYPICAL JOINT LAYOUT



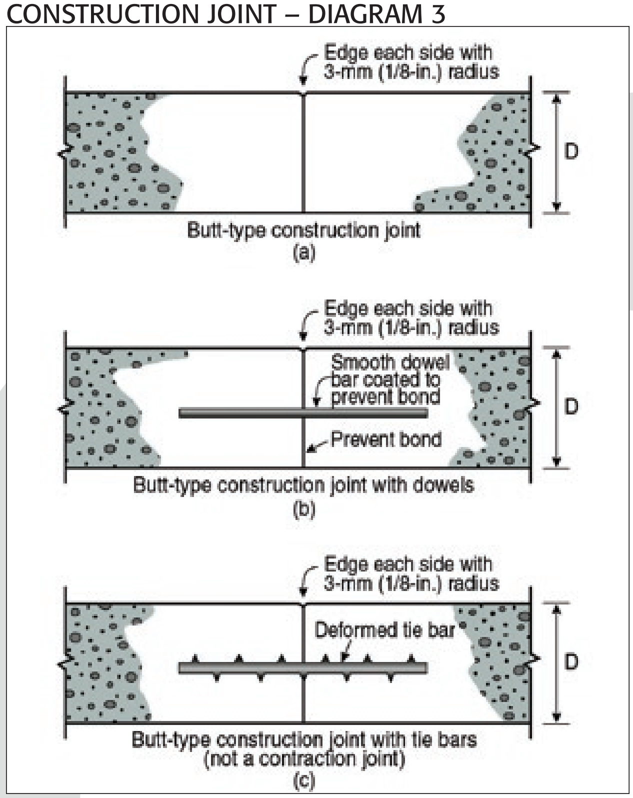
ISOLATION JOINT – DIAGRAM 1



CONTRACTION JOINT – DIAGRAM 2



CONSTRUCTION JOINT – DIAGRAM 3



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References:
1 CSA A23.1-04 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International
2 Design and Control of Concrete Mixtures – 7th Canadian Edition, Cement Association of Canada
3 Slabs on Grade, ACI Concrete Craftsmen Series CCS-1, American Concrete Institute
4 Concrete in Practice #6 – Joints in Concrete Slabs on Grade, National Ready Mixed Concrete Association

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TECHNICAL SPECIFICATIONS

Concrete Basics – Slump Test

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CSA A23.2 - 5C

A small variation in slump caused by improper procedure or equipment, may cause the rejection of an entire load of concrete. A little extra effort to observe good practice is the key to ensure that the concrete properties are properly evaluated.

1. **SAMPLING:** Obtain a representative 30 L grab sample from between the 10% and 90% points of discharge.
2. After moistening the slump cone, place it on a moist, smooth, non-absorbent, level & stable surface which is large enough to accommodate the foot lugs.
3. Standing on the foot lugs throughout the test, fill the cone one third by volume and rod 25 times with a 16 mm diameter x 600 mm long hemi-spherically tipped steel rod. (DO NOT USE any other substitute for this rod.) The rodding should be distributed evenly over the cross section of the sampling.
4. Fill the cone to two-thirds of its volume and rod 25 times as above with the rod just penetrating into the first layer.

Photo Courtesy of CAC

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Photo Courtesy of RMCAO

Photo Courtesy of CAC

5. Fill the cone to overflowing and rod 25 times as above with the rod just penetrating into the second layer. Add additional concrete to keep an excess of concrete in the mold at all times.

6. Strike off the excess concrete with the rod so that the cone is exactly full. Remove all spilled concrete from around the base.

7. Lift the cone vertically with a slow even motion, taking approximately 5 seconds to remove the cone.

8. Lay the rod across the top of the slump cone and measure the amount of the slump to the nearest 10 mm from the bottom of the rod to average top of the slumped concrete.

9. The test for slump shall be completed within 10 minutes of obtaining the concrete sample.

References:
CSA A23.2-04 - 5C Slump of Concrete

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Sealers for Concrete Flatwork

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Exposed concrete surfaces can benefit significantly from the application of concrete sealers to repel the infiltration of water, chlorides and provides short term protection from chemical spills and stains.

In general, there are two types of sealers available for use:

- **Film Forming Sealers** – Sealers that bond to the top surface of the concrete provide a barrier to te ingress of liquids.
- **Penetrating Sealers** – Sealers that are absorbed into the concrete surface and block the pore structure of the concrete preventing further water penetration.

Photo courtesy of Euclid Admixture Canada

Selection of the proper concrete sealer is based upon understanding the required concrete surface finish and the exposure conditions and traffic type (vehicles, pedestrian, etc.) that the sealer will be exposed to. It is strongly recommended that you discuss your application with the sealer manufacture prior to the start of the project. The factors that should be considered include:

- Type of surface finish
- Whether the surface is external or internal

Photo courtesy of Euclid Admixture Canada

- Intended use of the surface and traffic type
- Ease of reapplication of the sealer
- Health and Safety considerations (water based versus solvent based)

General Film Forming Sealers (Surface) Considerations:

- Ensure that the previous coat of sealer has properly cured. Dry does not mean cured (follow the manufacturer's recommendations)
- Do not apply to surfaces that are defective or weakened
- Do not apply surface sealer until moisture of the concrete is such that alkali and salts will not be trapped within the concrete (typically 14 – 28 days)
- Allow surface to thoroughly dry after cleaning
- Ensure that concrete is not sweating prior to application of the surface sealer (rain, fog, high humidity, etc.)
- Do not over apply sealers. Take precautions so puddling in joints or textured areas are minimized

Photo courtesy of Euclid Admixture Canada

Photo courtesy of Euclid Admixture Canada

General Penetrating Sealer (Silanes/Siloxanes) Considerations

- Can be applied to newly cured, or old concrete (typically 28 days old). If there are any concerns you should perform a penetration test as per the manufacturer's recommendations
- Remove all foreign substances that could prevent absorption of sealer prior to application
- When applying 2 coats let the concrete surface absorb the first solution and follow immediately with a second application before the surface dries
- Contact manufacturer if surface is to be treated following a penetrating sealer

Curing/Curing & Sealing General Considerations

- Materials must meet ASTM C-309 or ASTM C-1315 specification requirements
- Curing/Curing & Sealing compounds both form a membrane or film on the concrete surface to retain moisture. Cure and seals offer added benefits of long-term protection and improved appearance
- Apply liquid membrane curing or curing and sealing compound as soon as surface water has evaporated and final finishing operations have been completed
- Do not over apply. This can lead to blistering and peeling
- Do not apply cure or cure and seal if the dew point is such that sweating is occurring on the concretes' surface

References:

1 Penetrating Sealers for Decorative Concrete, Concrete Construction, August 2003

2 Sealers for Exposed Concrete Flatwork, Cement & Concrete Association of Australia, November 2003

3 Acrylic Sealers for Exterior Flatwork, Concrete Construction, January 2001

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