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 effect 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 A23.1-14 - Concrete Materials and Methods of Concrete Construction, Tables 1 - 4, outline the minimum durability requirements.
Definitions of C, F, N, A, S and R Classes of Exposure

(See Clauses 3, 4.1.1.1.1, 4.1.1.1.3, 4.1.1.5, 4.1.1.8.1, 4.1.2.3, 4.4.4.1.1.1, 4.4.4.1.1.2, 6.1.4, 6.6.7.5.1, 8.12.1, 9.1, L.3, and R.1, Tables 2, 3, and 17, and Annex L.)

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 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 structures exposed to seawater located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.

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 structures exposed to seawater. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.

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 that when in service is neither exposed to chlorides nor to freezing and thawing nor to sulphates, either in a wet or dry environment. Examples: footings and interior slabs, walls, and columns.

N-CF Interior concrete floors with a steel-trowel finish that are not exposed to chlorides, nor to sulphates either in a wet or dry environment. Examples: interior floors, surface covered applications (carpet, vinyl tile) and surface exposed applications (with or without floor hardener), ice-hockey rinks, freezer warehouse floors.

A-XL 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 might be generated, with higher durability performance expectations than A-1 class.

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 might be generated. Examples: reinforced beams, slabs, and columns over manure pits and silos, canals, and pig slats; and 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, and 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., forcemains); 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 exposures (Tables 2 and 3).

S-2 Concrete subjected to severe sulphate exposure (Tables 2 and 3).

S-3 Concrete subjected to moderate sulphate exposure and to seawater or seawater spray (Tables 2 and 3).

R-1 Residential concrete for footings for walls, columns, fireplaces and chimneys.

R-2 Residential concrete for foundation walls, grade beams, piers, etc.

R-3 Residential concrete for interior slabs on ground not exposed to freezing and thawing or deicing salts.
Table 1 (Concluded)

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. All classes of concrete exposed to sulphates shall comply with the minimum requirements of S class noted in Tables 2 and 3. In particular, Classes A-1 to A-4 and A-XL in municipal sewage elements could be subjected to sulphate exposure.
5. No hydraulic cement concrete will be entirely resistant in severe acid exposures. The resistance of hydraulic cement concrete in such exposures is largely dependent on its resistance to penetration of fluids.
6. Decision of exposure class should be based upon the service conditions of the structure or structural element, and not upon the conditions during construction.

<table>
<thead>
<tr>
<th>Class of exposure*</th>
<th>Maximum water-to-cementing materials ratio†</th>
<th>Minimum specified compressive strength (MPa) and age (d) at test‡,***</th>
<th>Air content category as per Table 4</th>
<th>Curing type (see Table 19)</th>
<th>Chloride on penetrability requirements and age at test‡‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-XL or A-XL</td>
<td>0.40</td>
<td>50 within 56 d</td>
<td>1 or 2§</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>C-1 or A-1</td>
<td>0.40</td>
<td>35 within 56 d</td>
<td>1 or 2§</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>C-2 or A-2</td>
<td>0.45§§</td>
<td>32 at 28 d</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>C-3 or A-3</td>
<td>0.50</td>
<td>30 at 28 d</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C-4** or A-4</td>
<td>0.55</td>
<td>5 at 28 d</td>
<td>2</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>F-1</td>
<td>0.50</td>
<td>30 at 28 d</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>F-2 or R-1 or R-2</td>
<td>0.55</td>
<td>25 at 28 d</td>
<td>2††</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>N</td>
<td>As per the mix design for the strength required</td>
<td>For structural design</td>
<td>None</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>N-CF or R-3</td>
<td>0.55</td>
<td>25 at 28 d</td>
<td>None</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>S-1</td>
<td>0.40</td>
<td>1 or 2§</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>S-2</td>
<td>0.45††</td>
<td>1 or 2§</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>S-3</td>
<td>0.50††</td>
<td>1 or 2§</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

*See Table 1 for a 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 provided that freezing and thawing and de-icer scaling resistance have been demonstrated to be satisfactory. The water-to-cementing materials ratio shall not be exceeded for a given class of exposure.
‡In accordance with CSA A23.2-23C, an age different from that indicated may be specified by the owner. Accelerated moist curing in accordance with CSA A23.2-23C may be specified by the owner; in such cases, the age at test shall be 28 d. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, without calcium nitrite, shall be prequalified to meet the requirements for the permeability index in this Table. For field testing, the owner shall specify the type of specimen and location from which it is taken. If cores are required, the concrete cores shall be taken in accordance with CSA A23.2-23C. §Air content category 1 shall be used for concrete exposed to freezing and thawing. Air content category 2 shall be used for concrete not exposed to freezing and thawing.

‡‡For class of exposure C-4, S-1, S-2, and S-3, 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 required.
**Table 2 (Concluded)**

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


§§The maximum water-to-cementing material ratio for HVSCM-1 concrete in a C-2 exposure shall not exceed 0.40.

***A different age at test may be specified by the owner to meet structural or other requirements.

†††For concretes made with MSLb or HSLb blended cements or combinations of portland-limestone cement and supplementary cementing materials, the water to cementing materials ratio for S-2 and S-3 classes of exposure shall be no greater than 0.40. This maximum water to cementing materials ratio for all sulphate exposures, in addition to the high levels of SCMs required, will help ensure high resistance to sulphate penetration. This provides an additional safeguard until sufficient data on field performance of concrete with these binders can be generated.

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### 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, and L3 and Tables 1, 7, 24, and 25.)

<table>
<thead>
<tr>
<th>Class of exposure*</th>
<th>Degree of exposure</th>
<th>Water-soluble sulphate (SO₄)† in soil sample, %</th>
<th>Sulphate (SO₄) in groundwater samples, mg/L‡</th>
<th>Water-soluble sulphate (SO₄) in recycled aggregate sample, %</th>
<th>Cementing materials to be used§ ††</th>
<th>Performance requirements§, §§</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maximum expansion when tested using CSA A3004-C8 Procedure A at 23°C, %</td>
</tr>
<tr>
<td>S-1</td>
<td>Very severe</td>
<td>&gt; 2.0</td>
<td>&gt; 10 000</td>
<td>&gt; 2.0</td>
<td>HS**, HSB, HSLb*** or HSe</td>
<td>0.05</td>
</tr>
<tr>
<td>S-2</td>
<td>Severe</td>
<td>0.20–2.0</td>
<td>1500–15 000</td>
<td>0.60–2.0</td>
<td>HS**, HSB, HSLb*** or HSe</td>
<td>0.05</td>
</tr>
<tr>
<td>S-3</td>
<td>Moderate (including seawater exposure*)</td>
<td>0.10–0.20</td>
<td>150–1500</td>
<td>0.20–0.60</td>
<td>MS, MSe, MSLb***, LH, LHb, HS**, HSB, HSLb*** or HSe</td>
<td>0.10</td>
</tr>
</tbody>
</table>

*For sea water exposure, also see Clause 4.1.1.5.

†In accordance with CSA A23.2-3B.

‡In accordance with CSA A23.2-2B.

§Where combinations of supplementary cementing materials and portland or blended hydraulic cements are to be used in the concrete mix design instead of the cementing materials listed, and provided they meet the performance requirements demonstrating equivalent performance against sulphate exposure, they shall be designated as MS equivalent (MSe) or HS equivalent (HSe) in the relevant sulphate exposures (see Clauses 4.1.1.6.2, 4.2.1.1, and 4.2.1.3, and 4.2.1.4).

**Where MSLb or HSLb cements are proposed for use, or where MSe or HSe combinations include Portland-limestone cement, they must also contain a minimum of 25% type F fly ash or 40% slag or 15% metakaolin (meeting Type N pozzolan requirements) or a combination of 5% Type SF silica fume with 25% slag or a combination of 5% Type SF silica fume with 20% Type F fly ash. For some proposed MSLb, HSLb, and MSe or HSe combinations that include Portland-limestone cement, higher SCM replacement levels may be required to meet the A3004-C8 Procedure B expansion limits. Due to the 18-month test period, SCM replacements higher than the identified minimum levels should also be tested. In addition, sulphate resistance testing shall be run on MSLb and HSLb cement and MSe or HSe combinations that include Portland-limestone cement at both 23 °C and 5 °C as specified in the table.
### Table 3 (Concluded)

The requirement for testing at 5 °C does not apply to MS, HS, MSb, H5b, and MSe and HSe combinations made without portland limestone cement.

If the increase in expansion between 12 and 18 months exceeds 0.03%, the sulphate expansion at 24 months shall not exceed 0.10% in order for the cement to be deemed to have passed the sulphate resistance requirement.

For demonstrating equivalent performance, use the testing frequency in Table 1 of CSA A3004-A1 and see the applicable notes to Table A3 in A3001 with regard to re-establishing compliance if the composition of the cementing materials used to establish compliance changes.

Type H5 cement shall not be used in reinforced concrete exposed to both chlorides and sulphates, including seawater. See Clause 4.1.1.6.3.

If the expansion is greater than 0.05% at 6 months but less than 0.10% at 1 year, the cementing materials combination under test shall be considered to have passed. Limestone fillers shall not be used in concrete for any S class exposure listed in Tables 1 to 3. Portland-limestone cement shall not be used as the sole cementitious material in concrete for any S class exposure listed in Table 1 to 3. However, blended hydraulic cements, or combinations of portland-limestone cement and the minimum levels of supplementary cementing materials listed in Table 9 of A3001 and also meeting the test requirements of Table 5 in A3001, may be used in any S class exposure listed in Tables 1 to 3.

### CSA A23.1 - Table 4

<table>
<thead>
<tr>
<th>Air content category</th>
<th>10 mm</th>
<th>14-20 mm</th>
<th>28-40 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1†</td>
<td>6-9</td>
<td>5-8</td>
<td>4-7</td>
</tr>
<tr>
<td>2</td>
<td>5-8</td>
<td>4-7</td>
<td>3-6</td>
</tr>
</tbody>
</table>

*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.