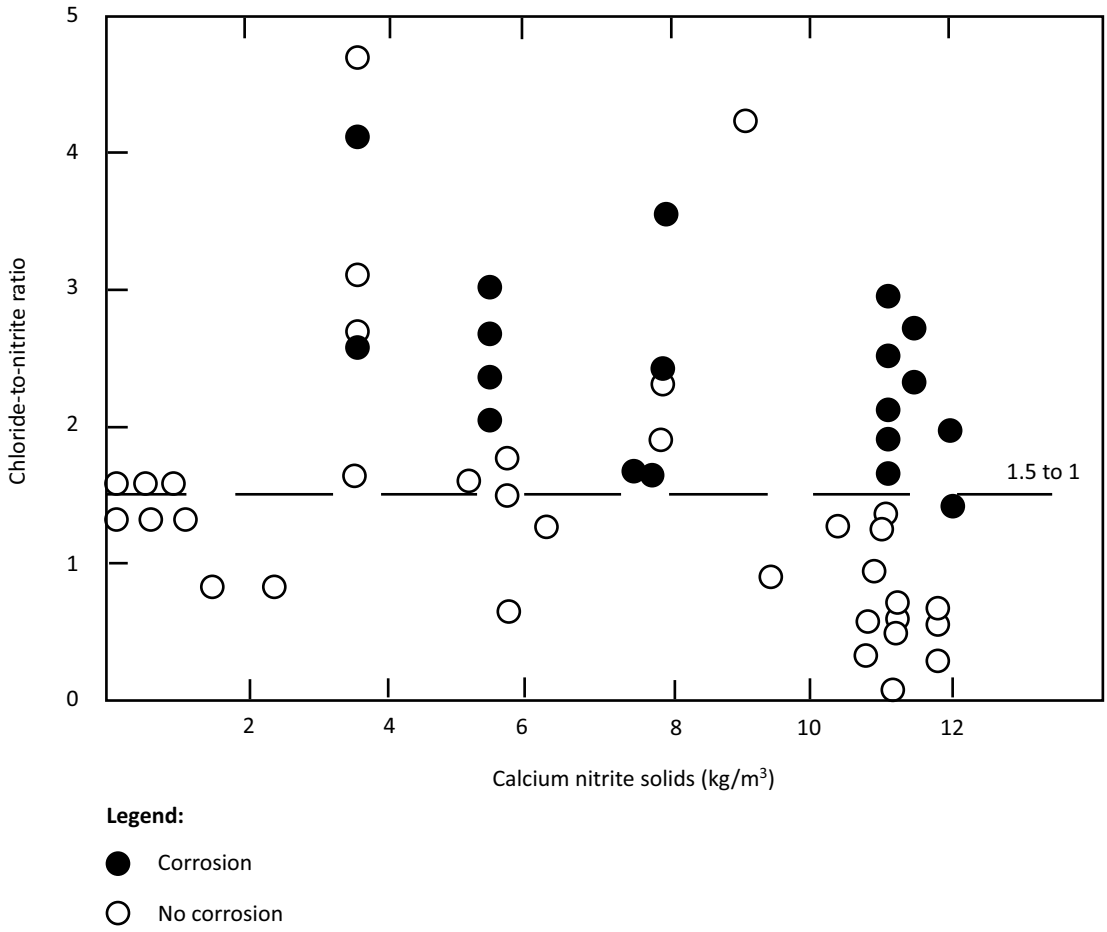
Figure C.2
Chloride-to-nitrite ratio versus calcium nitrite content
(See Clause C.9.1.)



Note: *Adapted from Berke and Rosenberg, 1989. Includes data from Grace Washington Research Centre, Solution Tests, Lollipop Tests, and FHWA (Federal Highway Administration) Outdoor Exposure Tests.*

Annex D (informative)
Testing and inspection

Note: *This Annex is not a mandatory part of this Standard.*

D.1 General

D.1.1
Quality control procedures should be established before the commencement of work. These include three components:

a) the contractor's quality assurance procedures;
b) inspection and testing by independent agencies; and
c) the review procedures by the designer, the engineer, or the architect designated to carry out these procedures.

D.1.2
The designer should specify the steps to be followed to verify that the contractor has implemented an appropriate quality assurance procedure. This verification may take the form of the minutes of an initial project meeting or it may be confirmed in a formal verification method statement to be provided by the contractor.

D.1.3
In addition to the minimum procedures as outlined in Clause 11.2, a form should be provided that the contractor can sign off on before concrete is placed in any location. The independent inspection and testing company should also sign off on the form when appropriate. The form should be delivered to the designer as evidence of compliance with the quality assurance procedures.

D.2 Checklist
Figure D.1 is a sample checklist for inspection and testing. The various items may be the responsibility of an engineer, architect, testing agency, or contractor, as appropriate.

Figure D.1
Sample checklist for inspection and testing
(See Clause D.2.)

General

☐ Record results of all inspections and tests

☐ Organize concrete quality control procedures to comply with Clause 4.4 of CSA A23.1

Concrete quality

☐ Review concrete (Clause 6.1) and stressing pocket grout (Clause 8.2), mix design, admixtures (Clause 6.1.4), aggregates (Clause 6.1.5), and air-entraining agents

☐ Verify dosage of corrosion inhibitor on delivery ticket

Test trial mixes to determine

☐ Permeability of concrete (Clauses 6.1.2.1 to 6.1.2.3)

☐ Slump

☐ Air content of plastic concrete

☐ Air-void structure (spacing factor) of hardened concrete (Clause 4.3.3 of CSA A23.1)

☐ Water-soluble chloride ion content (Clause 6.1.3)

☐ Air content at point of deposition

Formwork

☐ Formwork and screed elevations are as shown on the drawings for drainage slopes and drain elevations (Clauses 7.5.1 to 7.5.5, 7.5.10, and 10.2)

☐ Expansion joint hardware is installed at a proper width to accommodate volume change and thermal movements

☐ Shoring

☐ Corrosive de-icing chemicals are not used on the formwork (Clause 10.3)

☐ In-place strength of the concrete is at least 75% of the 28 d strength before removal of formwork (Clause 10.9)

☐ Installation of reshores follows almost immediately upon the stripping so that no large areas are left unshored (Clause 10.9.3)

Reinforcement

For epoxy-coated reinforcement:

☐ Contractor understands the procedures for shipping, handling, storing, and placing epoxy-coated bars to minimize damage to the coating

For reinforcement and prestressing tendons, after trades have finished working on deck:

☐ Quantity

☐ Spacing

(Continued)

Figure D.1 (Continued)

☐ Type of support chairs and spacing (Clause 10.4.1)

☐ Chaired height

☐ Concrete cover (Clauses 7.3.8, 9.3.2, 9.4, and 10.6.5 and Table 1)

☐ Side cover to reinforcement at vertical and inclined surfaces and at balustrade dowels (Clauses 7.3.8 and 10.4.2)

☐ Both ends of dowels at floor construction joints are securely supported

☐ Tie wires (Clause 10.4.3)

☐ Handling, storage, and protection of epoxy-coated bars

☐ Damaged or uncoated areas of epoxy-coated bars, before being placed in structure, to determine which are to be rejected and which are to be repaired

☐ Surface preparation and adequacy of repair of uncoated areas or damaged areas of coating on epoxy-coated bars

☐ Welded wire reinforcement is supplied flat in sheets or straightened if supplied in rolls (Clause 6.4), that it is placed with specified cover, and that it is lapped the specified amount

For tendons (Clauses 6.5 and 8, and CSA A23.1):

☐ Qualifications of supervisor and inspector (Clauses 8.5.1 and 8.5.2)

☐ Corrosion-protection coating application to tendons in shop to provide complete continuous coverage, with no uncoated portions

☐ Post-tensioning hardware is protected by an effective and durable coating and that the coating is not damaged

☐ Tendon sheathing and corrosion-protection coating for unbonded tendons conforms with this Standard

☐ Thickness of tendon sheath is not less than 1.5 mm (CSA A23.1)

☐ Placement of prestressing anchors

☐ Sheaths on unbonded tendons for tears and punctures and subsequent repair

☐ Watertight connection of tendon to anchorage

☐ Evidence that water has entered the tendon sheath during manufacture, shipping, storage, and construction. *If it has, ensure that the tendon is rejected.*

☐ Voids are filled with corrosion-inhibiting material, including voids near anchorages

☐ Covers of the ends of prestressing tendons, i.e., covers of tendon stubs

☐ Surface preparation and installation procedures for stressing pocket grout

☐ Taped double sheath where a tendon extends through a construction joint (Clause 8.3.2)

☐ Tendons are not located within 300 mm of the edge of drains (Clause 8.4)

☐ Quantity, placement, and chair heights

(Continued)

Figure D.1 (Continued)

☐ Protection from weather, protection of tendons during shipping and storage, and protection of ends of tendons after placement in formwork until anchors are sealed
Concrete placement
☐ Water-soluble chloride ion content from test cylinders (Clause 6.1.3)
☐ Preparation of surfaces where plastic concrete is placed against hardened concrete (Clause 7.4.1.2)
☐ Environmental conditions
☐ Concrete placement procedures
☐ Workers do not thrust their shovels into the concrete and damage post-tensioning sheaths
☐ Concrete vibration procedures
☐ Compaction
☐ Entire slab surface complies with the minimum slope to drain requirements (Clause 7.5)
☐ Slab thickness
☐ Finishing is not started while there is bleed water on the slab
☐ Slab surface is not overworked (Clause 10.7)
Concrete curing
☐ Method, temperature, and duration of curing (Clause 10.8)
☐ Surface is kept continuously moist during curing of cast-in-place concrete (including on weekends)
Protection systems
☐ Curing compounds are not used on floor surfaces or other surfaces intended for a protection system (Clause 10.8.3)
☐ Acid is not used on concrete surfaces as a surface preparation for a moisture-barrier system (Clause 10.11.1)
☐ Acid is not used on cast-in-place prestressed structures (Clause 10.11.2)
☐ Preparation of the surface for the application of protection system, including treatment of cracks, contraction joints, and construction joints in accordance with protection system manufacturer's recommendations (Clauses 10.12 and 10.13)
☐ Details where the protection system joins drains and expansion joints, and at terminations (Clause 7.3.9.3)
☐ Moisture content of concrete before applying protection system, the ambient air temperature, and the relative humidity (Clause 10.12)
☐ Substrate temperature is at least Celsius degrees above the dew point
☐ Application rate of sealers and depth of penetration
☐ Height of protection system at vertical surfaces (Clauses 7.3.9.2 and 7.3.10)

(Continued)

Figure D.1 (Concluded)

☐ Adhesion, pinholing, gas bubbles, intercoat adhesion, and the effect of wearing course application methods on the membrane by means of cut tests; and the substrate adhesion and intercoat adhesion of thin-membrane protection systems by means of pull tests
☐ Formulation of the asphalt wearing course to resist rutting, the formulation of mastic wearing course to resist cracking, and the hardness of the mastic
☐ Membrane will not be punctured by aggregates in the wearing course
☐ Compaction tests and thickness tests on asphalt
☐ Surface preparation and paint coat thicknesses on painted structural steel, including sharp edges and corners
☐ Concrete surface preparation may be referenced under ACI 515.3R and ICRI 310.2R
Joints
☐ Construction joints (Clause 7.4.1)
☐ Expansion joints and sliding joints (Clause 7.4.2)
☐ Chases at expansion joints are the correct width and depth to receive nosings for the seals
☐ Sliding joint bearing material is set back from face of joint and that there are no concrete bridges across joint (Figure H.7)
☐ No contact of dissimilar metals (Clause 6.2)
☐ Members at sliding joints bear on the sliding material and are not in contact with the concrete of the supporting member
☐ Surface preparation and application of joint sealants to contraction joints (Clause 7.4.3.5)
☐ Expansion joint seals are installed at a proper width to accommodate volume change and thermal movements
Connections
☐ Connection hardware for precast members such as balustrades is installed with the hardware surface parallel to the concrete surface to accommodate movement without binding on the concrete
☐ At holes slotted to permit movement, there is adequate space from the fastener to the edge of the slot and that the fastener is not tightened to the extent that movement is prevented
☐ Sliding joints are not seized
Drainage
☐ Material used for drains (Clause 6.3.2)
☐ Drain location (Clauses 7.5.6 and 7.5.12)
☐ Drainage and leakage of traffic topping surface and drain pipes, by ponding with water or by spraying with water where ponding is not practical
Miscellaneous
☐ Material used for electrical conduits, boxes, portions of drain pipe within slab, etc. (Clauses 6.3, 7.6.1, and 7.6.2)
☐ Heating cables and pipes (Clause 7.7)

Annex E (informative)
Maintenance

Note: *This Annex is not a mandatory part of this Standard.*

E.1 Routine maintenance

Routine maintenance is essential to maintain the strength, structural integrity, and safety of the structure throughout its design service life (see Parking Consultants Council, 2006). Inspections should take place at regularly scheduled intervals (e.g., a walk-through survey annually and a more extensive documented condition audit about every three years). Any leakage should be immediately repaired to prevent corrosion and loss of strength. The cost of repairs to protection systems is a small fraction of the cost of repairing consequential damage to the structure.

Where the structure is concealed, inspection should include the exposure of portions of the structure in a sufficient number of areas to be able to make a reasonably reliable assessment of the structure's condition. In steel structures, this should include examination of the steel supporting members and their connections, bolts, and welds for loss of strength due to corrosion.

The inspection should be carried out under the direction of personnel knowledgeable in parking structure deterioration and repair.

Table E.1 contains recommendations for routine maintenance. Additional information is provided in Clause E.6.

E.2 Post-tensioned structures

Special expertise is necessary in the inspection of post-tensioned structures, as corroding tendons are not necessarily evident to external observation. A significant percentage of tendons can fail without any outward manifestation of tendon failure or structural distress. If tendon corrosion is suspected, detensioning and removal of some tendons for examination is sometimes necessary. This should be done under the direction of a professional engineer experienced in structural design and investigation of deterioration of post-tensioned parking structures.

E.3 Snowploughing

Snowplough blades with rubber edges or equipped with shoes that raise the blade above the floor surface will minimize damage to the garage but will not remove snow and ice down to the bare surface as required by many owners for public safety reasons. Ploughing at an angle of 75° or less to the direction of the expansion joint can help to reduce damage to the joint and joint hardware (see Chrest *et al.,* 2001).

If the roof has not been designed for the weight of piled snow, the snow should be removed from the roof rather than piled. Because of the difficulty in controlling where and how much snow is piled, snow should not be piled on the roof.

Areas around snow melters should be designed for the added weight of snow that will be ploughed and temporarily piled up until it can be fed into the snow melter.

E.4 De-icers

E.4.1

Ammonium nitrate and ammonium sulphate, which have been sold as de-icers, react chemically with all forms of concrete in the presence of water and cause disintegration even at room temperature. Their use should be strictly prohibited (see Canadian Parking Association, 2005).

E.4.2

The use of calcium chloride or sodium chloride to melt snow and ice should be minimized. The use of magnesium chloride should be avoided since it can be harmful to concrete (see Lee *et al.,* 1998; Moukwa, 1990; and Santhanam *et al.*, 2003). Both calcium chloride and calcium magnesium acetate are also known to be harmful to concrete (see Lee *et al.*, 1998; Santagata and Collepardi, 2000; and Cody *et al.*, 1996). Urea is least harmful. It does not corrode the steel embedded in the concrete; however, local environmental regulations should be reviewed to determine whether its use is acceptable.

E.5 Need for expert advice and report

The structure is in need of more extensive investigation or repair if any of the following is observed:

a) spalled or delaminated floors or columns (delamination is not always visually evident; it can be detected by a hollow sound during a chain drag or hammer sounding survey);
b) deteriorated or leaking expansion joints and joint sealant;
c) salt deposits or rust stains on the top, edges, or underside of the slabs, or on columns, walls, or balustrades; or
d) corrosion of steel beams and their connections, bolts, and welds.

If evidence of any of the above is found, an inspection under the supervision of a licensed professional engineer experienced in the design and evaluation of parking structures should be undertaken, and any necessary repairs carried out within a prioritized time schedule set out in the engineer's report. All leakage should be corrected as soon as possible and not be allowed to continue for years. The report should identify where repairs are required immediately for public safety reasons.

E.6 References

Canadian Parking Association

Technical Bulletin No. 2
Parking Facility Maintenance Manual, 2005

Other publications

Chrest, A.P., Smith, M.S., and Bhuyan, S. 2001. *Parking Structures, Planning, Design, Construction, Maintenance and Repair.* Third Edition. Boston: Kluwer Academic Publishers.

Cody, R.D., Cody, A.M., Spry, P.G., and Gan, G.-L. 1996. Experimental Deterioration of Highway Concrete by Chloride Deicing Salts. *Environmental & Engineering Geoscience* 2 (4): 575–588.

Lee, H., Cody, R.D., Cody, A.M., and Spry, P.G. 1998. Effects of Various Deicing Chemicals on Pavement Concrete Deterioration. *Mid-Continent Transportation Symposium Proceedings:* 151–155.

Moukwa, M. 1990. The Attack of Cement Paste by $MgSO_4$ and $MgCl_2$ from the Pore Structure Measurements. *Cement and Concrete Research* 20: 148–158.

Parking Consultants Council. 2006. *Parking Garage Maintenance Manual*. Washington, DC: National Parking Association, Parking Consultants Council.

Santagata, M.C., and Collepardi, M. 2000. The Effect of CMA Deicers on Concrete Properties. *Cement and Concrete Research* 30: 1389–1394.

Santhanam, M., Cohen, M., and Olek, J. 2003. Study of Magnesium Ion Attack in Portland Cement Mortars. *Proceedings from the 11th International Congress on the Chemistry of Cement:* 1460–1474.

Table E.1
Recommended maintenance
(See Clauses 0.4 and E.1.)

Item	Months				
	1	3	6	12	Other
Cleaning					*
Sweeping/cleaning localized	D†	M‡			
Sweeping/cleaning all area		M			
Wash parking floors			D	M	
Clean debris from expansion joints	D	M			
Plumbing					
Check floor drain operation; empty sediment buckets	D	M			
Protection system					§
Check for leaks in a) joint sealants; b) expansion joints; and c) floor membrane areas.			D	M	
Check for deterioration in a) wearing course; and b) sealer.			D	M	
Repair worn spots in membrane and wearing course				M	As needed
Reapply sealer					**
Structural system					
Check a) concrete surface deterioration; b) water leakage; c) concrete cracking or delamination; d) structural steel corrosion (e.g., beams, columns, connections, bolts, and welds); and e) painted and galvanized metal surface condition.			D	M	

(Continued)

Table E.1 (Concluded)

Item	Months				
	1	3	6	12	Other
Check exposed tendon stressing pockets for cracks, shrinkage, corrosion products, and dampness			D	M	
For expert evaluation only (see Clauses B.5 and E.5)					
Perform corrosion survey on representative area of top bars in concrete members					††
Check cathodic protection system					‡‡

* *In freezing weather, heated garages sometimes need more frequent cleaning as a result of melting deposits from the undercarriage of vehicles.*
† *D = desirable frequency.*
‡ *M = minimum frequency.*
§ *Joint sealants generally require localized repairs annually and sometimes need to be completely replaced at 7 to 10 yr intervals.*
** *Reapply at approximately 5 yr intervals or as recommended by the manufacturer. The reapplication period for sealers depends on many factors. High-wear areas are likely to require more frequent reapplication. Tests of in situ materials might be required in order to determine when reapplication is necessary. See Annex A.*
†† *Consideration should be given to carrying out a corrosion survey before the warranty on the protection system expires and periodically thereafter if chloride penetration into the concrete is suspected.*
‡‡ *See Annex B for information on cathodic protection system maintenance.*