Calgary

Maintenance of Structural Components in Higher Risk* Buildings

An Owner's Best Practice Guide

* Higher Risk Buildings Covered in this Guide: Enclosed Hockey, Skating and Curling Rinks • Exterior Exposed Structural Elements (e.g. balconies) • Indoor Pools (Natatoriums) • Industrial Facilities with Humid Environments (e.g. Compost Facilities) • Salt Storage Structures • Parking Structures (Parkades) • Post-Tensioned Structures • Wash Bay / Car-Wash Structures

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1 Guide Overview

Building structural components and function can suffer from decay and deterioration if left without periodic maintenance. This can lead to a variety of concerns including public safety, increased liability and reduced building lifespan. This risk is accelerated in some environments deemed "aggressive"; these are facilities that may include excessive condensation, salts, de-icing chemicals, corrosive detergents, and sources of moisture. Structures in these environments are considered "Higher Risk".

This Guide is developed for Owners to better understand 'best practices' for structural maintenance while operating and maintaining "Higher Risk" structures. Structures in this Guide include:

- Enclosed Hockey, Skating and Curling Rinks
- Exterior Exposed Structural Elements (e.g. Balconies)
- Indoor Pools (Natatoriums)
- Industrial Facilities with Humid Environments (e.g. Compost Facilities)
- Salt Storage Structures
- Parking Structures (Parkades)
- **Post-Tensioned Structures***
- Wash Bay / Car-Wash Structures

An outcome of this Guide is to increase public safety, minimize maintenance costs and ensure repair efforts are implemented in a timely manner. This Guide focuses on structural specific items and does not cover maintenance of mechanical, electrical or other building systems. The Higher Risk structures covered in this Guide are not comprehensive of all potential aggressive environments, Owners should consult a professional engineer if unsure.

Owners should develop a preventative maintenance program to sustain the safety and durability of Higher Risk structures. Early signs of deterioration left unattended can lead to safety hazards for users, increased liability for Owners, and may require expensive corrective repair programs. The cause of any structural distress should be determined and repairs implemented as soon as possible, with safety issues addressed immediately.

The following tables describe common concerns that can be used as points of emphasis when assessing a particular Higher Risk structure. The associated Preventative Maintenance Program Type is identified as A, B or C.

***NOTE:** Post-tensioned structures are an exception to the aggressive environments generalization. These are considered Higher Risk by default due to the method of construction. Depending on the type of post-tensioning system, or facility moisture conditions, the risk of deterioration can vary widely. More information specific to post-tensioned structures is included in Appendix B.

Common Concerns In Higher Risk Structures & Maintenance Program Types

Building Use	Special Concerns	Recommended Maintenance	Preventative Maintenance Program Type
Enclosed Hockey, Skating and Curling Rinks	• In arenas with humidity levels greater than 40%, corrosion of steel components is common. This is typically noticed at roof level or column bases. • Timber structural elements are prone to decay (rot) when in contact with moisture for prolonged periods.	• Arena temperature held between 5°C to 8°C, with a relative humidity below 40%. • Recommend de-humidification unit to reduce humidity level below 40%.	A

Exterior Exposed Structural Elements	• Corrosion of steel framing.
	• Spalling of concrete, exposing steel reinforcements.
	• Timber not sheltered from snow, rain, and ultra violet light are particularly susceptible to decay (rot).
	• Timber beams projecting beyond roof edge.
	• Factors necessary for wood decay:
	  • Sustained wood moisture content (20%)
	  • Air
	  • Warm temperature
		• Review timber sealer. Exterior wood sealers are used to limit moisture penetration and reduce the potential for decay of exterior timber elements. Sealers have a finite service life and re-application is typically required throughout its service life.	A

Indoor Swimming Pools (Natatoriums)	• Moisture accumulation above pool ceilings due to poor ventilation can lead to corrosion of structural steel. • Corrosion or steel structures, typically at roof level or at column base. • Decay (rot) of timber elements when in contact with moisture for prolonged periods. • Concrete delamination. • Stainless steel stress corrosion cracking from chlorine-containing chemicals.	• Natatorium temperature held 2°C to 3°C above water temperature, to minimize pool evaporation and maintain 40% to 60% relative humidity (minimize condensation). • Chlorine containing chemical vapors from pool water can condense onto structural components. Annual cleaning is recommend.	A
Industrial Facilities with Humid Environments	• Corrosion of steel framing. • Decay (rot) of timber elements when in contact with moisture for prolonged periods. • Plenum spaces above ceilings are prone to moisture accumulation due to poor ventilation.		A

Common Concerns In Higher Risk Structures & Maintenance Program Types Table continued on next page

Building Use	Special Concerns	Recommended Maintenance	Preventative Maintenance Program Type
Salt Storage Structures	• Corrosion of steel framing. • Concrete delamination.		A
Wash Bay/ Car-Wash Structures	• Corrosion of steel framing. • Decay (rot) of timber elements when in contact with moisture for prolonged periods. • Deterioration and/or debonding of masonry and mortar joints. • Moisture infiltration into load bearing masonry walls, damaging insulation and wall finishes. • Plenum spaces above ceilings are prone to moisture accumulation due to poor ventilation.		A
Parking Structures (Parkades)	• Spalled or delaminated concrete at slabs, columns or walls. • Debonded or visibly damaged traffic deck coating membrane. • Deteriorated or leaking expansion joints, cracks, or sealant joints. • Salt deposits or rust stains on slabs, columns or walls. • Corrosion of steel beams, columns, bolts or welds. • Snowplows can damage structure as well as joint sealants, isolation-joint seals, and deck coatings.	• Dry sweeping should be done at least monthly. • Road salt accumulates over winter months and should be removed annually (at minimum) each spring by flushing the surface with large volumes of water under low to moderate pressure or using wet scrub equipment. • A second washdown in the fall to remove surface debris and contaminants. • Critical areas that tend to get a higher buildup of salts, such as entrances, exits, and flat or ponded areas, should be rinsed more frequently. • Drains should be flushed carefully to avoid accumulation of sand, dirt, or debris into the drainage system. • Discuss with your snow removal contractors about using non-studded tires and equipping their plows with soft-tipped plow blades.	B

Common Concerns In Higher Risk Structures & Maintenance Program Types Table continued on next page

Building Use	Special Concerns	Recommended Maintenance	Preventative Maintenance Program Type
Post- Tensioned Structures	• Moisture ingress through slabs or at slab edges can cause corrosion related strand breakage and tension loss. • Mechanical damage from drilling, coring, saw-cutting or powder-actuated fasteners can cause strand breakage and tension loss. • Quality control related issues, resulting in inadequate tension applied to strands at original construction. • Parking decks and below grade slabs are at highest risk of moisture ingress, but roof slabs, balcony slabs, or even interior slabs can be exposed to moisture as a result of roof membrane or waterproofing failure, water incursions due to pipe breaks, or overland flooding.	• Engage an Engineering Professional to assess the condition and risk to the building's post-tensioning system. • Follow the recommendations of the Engineering Professional to implement a tension testing program, or other form of monitoring (i.e. acoustic monitoring), at the recommended intervals. • Test intervals will vary by building based on present and past condition of post-tensioning system, and risk of future corrosion-related deterioration. • Implement repairs to the post-tensioning system to replace broken strands. • Ensure all waterproofing and building envelope systems protecting the post-tensioning system are maintained regularly. • Implement strict requirements pertaining to tenant renovations or construction related activities that could damage your post-tensioning system.	C

Table A – TYPE A: Preventative Maintenance Program Tasks

Task	Performed By	Frequency
Self-performed reviews	Owner	Annual (12 months)
Professional condition assessment	Engineering Professional	5 years (Maximum) or as necessary following Owner self-performed review

Table B –TYPE B: Preventative Maintenance Program Tasks (Parkade)

Task	Performed By	Frequency
Self-performed reviews	Owner	Annual (12 months)
Parking deck dry sweep	Owner or 3rd Party Contractor	3 months
Parking deck wet scrub	Owner or 3rd Party Contractor	6 months
Drainage system cleaning/flush	3rd Party Contractor	12 months
Professional condition assessment	Engineering Professional	Recommended 3 years (5 years maximum) or as necessary following Owner self- performed review
Maintenance of the structure, waterproofing systems, and drainage system	Specialized Restoration Contractor with Engineering Professional	3 years

Table C– TYPE C: Preventative Maintenance Program Tasks (Post-Tensioned)

Task	Performed By	Frequency
Professional condition assessment*	Engineering Professional	5 years (Maximum) or at intervals recommended by Engineering Professional
Maintenance of waterproofing systems, roof membranes, balcony coatings, and building envelope components protecting post-tensioned slabs	Specialized Contractors with Engineering Professional	2 to 3 years or as recommended by Engineering Professional

***NOTE:** An Engineering Professional should be engaged by the Owner as follows:

- If there is doubt about the nature of your building's structure (whether it is post-tensioned or not);
- If you have confirmed the building is post-tensioned and need to understand its maintenance status;
- If you have previous engineering reports about the post-tensioning system with recommendations.

2 Review Types

Self-Performed Review

Annual reviews should be completed for evidence of condensation, water ingress, and observable structural deterioration. This type of review can be performed by the Owner, preferably a person familiar with the facility layout and operation.

Structure specific checklists are provided in **Appendix A** to guide Owners through the annual review. The checklist is intended to illustrate what structural elements are important for safety and durability, as well as provide examples of common deterioration or damage. While mechanical and electrical systems are not part of the structure, in some cases heating, drainage and ventilation systems are relied upon to avoid structural deterioration. For example clogged parkade trench drains, failed roof assemblies and ventilation systems no-longer de-humidifying the space. The deterioration of these systems may also be an early indicator of a corrosive environment, or failures in waterproofing systems that protect the structure. Review elements are divided into the following items:

A. Primary Structure: Primary structural elements necessary to support building loads. These include floor/roof construction, beams, columns, braces, and foundations (if observable).
B. Secondary Structure: Structural elements not part of the primary structure. Examples of these include structures supporting pool equipment, mechanical equipment, suspended ceiling hangers, overhead door frames, stair landings, treads and handrails.
C. Mechanical and Electrical Systems: These include ventilation and drainage systems which the structure specifically relies upon to mitigate deterioration. This does not include overall building mechanical and electrical systems used to operate the building.
D. Building Envelope: All components which separate the indoor conditioned environment from the outdoor unconditioned environment. These include roofing assemblies and perimeter cladding components.
E. Other: Deterioration of elements not listed elsewhere.

The annual inspection should cover all observable elements for each respective review item. Portions of dropped ceilings (ceilings tiles) or easily removed architectural finishes shall be temporarily removed to observe a minimum 2% of hidden structure. This does not include drywall ceilings or wall finishes. Within the "Higher Risk Structures – Owner Self-Performed Assessment Checklist", the Owner should evaluate each item according to the following criteria:

Condition Present	Condition Commentary
Yes	Type of deterioration visible. Further review or maintenance required.
No	Type of deterioration not visible. No action required.
Not Applicable	This item not applicable to the facility

Should any item under "Primary Structure" or "Secondary Structure" be marked as "Yes" in the Higher Risk Structures – Owner Self-Performed Assessment

Checklist, a Professional Condition Assessment under the supervision of an Engineering Professional registered in Alberta experienced in the design and evaluation of comparable structures should be undertaken. Regardless of assessment outcome, regular maintenance is recommended throughout the building's service life with maintenance programs noted in Tables A, B or C.

Professional Condition Assessment

Recommended Practice for Owners

Owners shall engage an Engineering Professional registered in Alberta to conduct a preliminary engineering assessment within the maximum scheduled frequency noted in Tables A, B, or C.

Owner Responsibilities

The project organization for a professional structural condition assessment is typically straightforward and involves the building Owner, or an entity acting on behalf of the Owner, contracting the engineering firm that undertakes the assessment. The contract should be put into writing and signed by both parties prior to the commencement of the project. In general, a building Owner has the following responsibilities:

- Enter into an appropriate services agreement with the Engineering Professional or engineering firm completing the professional structural engineering assessment.
- Provide information about their facility as well as a copy of the Owner self-performed checklist.
- Provide access to all areas of the building deemed necessary by the Engineering Professional to complete the assessment.
- Act on the recommendations of the assessment, especially in cases of public safety.
- Follow up with a detailed engineering assessment if recommended by the preliminary engineering assessment report.

Engaging Engineering Services

The Owner Self-Performed Checklist should be provided to the Engineering Professional at time of the initial request for engineering services. The building information and results of the Owner's self-performed review will be of value to the Engineering Professional to understand the nature of the Owner's request and the type of facility. This will also assist to estimate scope of work, time involved, and by consequence the engineering fees anticipated to perform the preliminary engineering assessment.

Generally an initial field visit will be required the first time an Engineering Professional works at the building to better understand Owner's concerns and present an accurate engineering services proposal, including scope of work and engineering fees involved.

Qualifications of Engineering Professional

Structural condition assessments should only be carried out by an Engineering Professional who is registered with the Association of Professional Engineers and Geoscientists of Alberta (APEGA). This Professional should have knowledge and experience in:

1. The occupancy, property, life expectancy, durability and reactivity of construction materials utilized in building construction;
2. Past and present methods of constructing buildings of similar use and material;
3. Failure mechanisms of structures and structural elements; and
4. .Structural engineering as it applies to the building being assessed.

The owner should request to review the Engineering Professional's resume, evaluating for appropriate qualifications (registered with APEGA) and similar project experience.

Overview of Preliminary Engineering Assessment

Visual condition survey of the building that is qualitative rather than quantitative. The use of the term "preliminary" is not intended to imply the preliminary assessment is incomplete or a precursor to a detailed assessment. Rather, the preliminary assessment is a stand-alone scope of work, and should comment on the general condition of the structure, and include a conclusion as to whether a detailed assessment is recommended or the need for any immediate corrective action.

Overview of Detailed Engineering Assessment

A preliminary assessment report may recommend a more comprehensive, detailed assessment. The Engineering Professional should clearly state the reason(s) for a detailed assessment and corresponding recommended assessment time frame. The risks/consequences of failing to complete a detailed assessment should be made clear to the Owner.

Field Evaluation

A field evaluation (site visit) by the Engineering Professional will be required at any level of professional assessment. When possible, the Engineering Professional performing the field evaluation should be accompanied by a building site representative (or person familiar with the building) who can:

- Provide access to various areas within the facility and describe their uses;
- Identify known areas of deterioration, distress, corrosion, cracking, settlement, or water leakage; and
- Provide a general building history.

The Engineer may encounter challenges when conducting a field evaluation if some structural elements in the facility are covered by finishes or are inaccessible due to height or other site constraints. Using their professional judgment, they may request that covered areas be exposed for assessment. Reference to available structural drawings can be crucial in this circumstance to determine the presence of critical structural elements/materials susceptible to deterioration within the particular area of concern. The Engineering Professional and Owner may mutually agree on the best approach to provide access or remove any building finishes, as necessary to carry out the observations (including engaging a contractor).

The Engineering Professional is responsible to visually review a reasonable amount of critical structural elements to fulfill their professional responsibility. If the Engineering Professional determines concealed structural elements need examination, the Owner must allow and facilitate the removal of finishes for the condition assessment.

Report Deliverables

Engineering Professionals must present their findings in a report addressed to the client at the completion of any preliminary or detailed assessment. The level of detail of the report depends on the original reason for the assessment and will match the degree of complexity of the assessment and analysis. Structural condition assessment reports contain statements of professional opinion and therefore must be sealed. The reports shall include:

- Purpose of the assessment;
- Reference documents reviewed as part of the assessment;
- Scope of service provided including any limitations;
- General description of the building and its structure;
- Summary of areas reviewed, personnel involved, methodology and observations;
- Analysis, conclusions and recommendations including the need for any immediate corrective action or additional assessment; and
- Estimated remediation and/or additional engineering design costs.

An example report table of contents is provided in **Appendix C**.

Owner Follow-Up

Follow Recommendations

The Owner is responsible for ensuring all recommendations described in the Engineering Professional's assessment report are followed. While the Owner's self-performed condition assessment checklist can be useful in determining which areas of the facility require further review, it does not replace a professionally conducted assessment. The Professional's assessment report is vital to communicate the extent of maintenance required, evaluate different repair options, and allow an Owner to develop a budget.

Any recommended maintenance or additional assessment should be performed within the time frame recommended by the Engineering Professional such that they are not left to deteriorate into unsafe conditions. An Owner may obtain a second opinion from another Engineering Professional if there is dispute over the recommended repair scope of work, or the expected costs associated with the work; however, the Owner should not delay or defer work that is deemed urgent or unsafe.

Transfer Recommendations between Owners and Operators

When Ownership changes, the current Owner should be responsible for providing the new facility Owner with maintenance recommendations, as well as completed previous maintenance and repair records, assessment reports, and review recommendations.

A

Checklists

Type A & B Structures

Structures Exposed To Aggressive Environments – **Type A Structures**

Owner Self-Performed Assessment Checklist

Date of Assessment					
Building Name					
Building Address					
Air Temperature / Relative Humidity	Air Temperature (°C):		Relative Humidity (%):		
Building Use					
Date of Construction	Year:				Unknown ☐
Last Maintenance	Year:				Unknown ☐
	If yes, describe work:				
Primary Structure Type	Cast-in-Place Concrete ☐	Precast Concrete ☐	Steel Framed ☐	Timber Framed ☐	Unknown Or other (specify):
Exterior Timber Elements	Yes ☐		No ☐		Unknown ☐
Number of Levels	Above-Grade:		Below- Grade:		
Other Details					

Common Concerns In Higher Risk Structures & Maintenance Program Types

Item	Observation (Examples of Typical Deterioration)	Condition Present?		
A – Primary Structure		**Yes**	**No**	**N/A**
1	Corrosion staining at steel beams/columns, connection plates, bolts, bracing, other structural steel components			
2	Spalled or delaminated concrete at slabs , columns, beams or walls as well as masonry walls			
3	Corrosion staining* at underside of concrete slabs, beams, surfaces of columns / walls			
4	Decay (rot) of wood framing at roof/floor sheathing, trusses, beams, columns			
5	Evidence of movement (cracking, spalling, separated joints, step cracking* in masonry walls, cracks in drywall, cracks in slabs-on-grade etc.)			
6	Active water ingress through below-grade foundation walls			
7	Other (specify)			
B – Secondary Structure		**Yes**	**No**	**N/A**
1	Damage, corrosion, or other deterioration of diving board platform, slide structure, other pool structures			
2	Damage, corrosion, or other deterioration of structures supporting mechanical equipment (corrosion of AHU/Condenser platforms)			
3	Damage, corrosion, or other deterioration at suspended ceiling structure (i.e. corroded hanger wires)			
4	Damage, corrosion, or other deterioration of stair landings, treads, handrails			
5	Damage, corrosion, or other deterioration of overhead door frames			
6	Exterior cladding, corroded connections, loose components.			
7	Other (specify)			
C – Mechanical and Electrical Systems		**Yes**	**No**	**N/A**
1	Dehumidification units are functional and operational.			
2	Sump frame and grate corrosion			
3	Trench drain frame and grate corrosion, debris accumulations			
4	Corroded light fixtures or electrical conduits			
5	Damaged, clogged or poorly draining roof or floor drains			
6	Cracked or leaking drain pipes.			
7	Other (specify)			

Common Concerns In Higher Risk Structures & Maintenance Program Types continued on next page

NOTE: Visual Examples included in Appendix D

Item	Observation (Examples of Typical Deterioration)	Condition Present?		
D – Building Envelope		**Yes**	**No**	**N/A**
1	Active water ingress through roof or walls			
2	Staining or evidence of past water ingress (i.e. efflorescence , debonded paint, stained insulation, damaged ceiling tiles)			
3	Water leakage through openings in roof/floor (i.e. unsealed pipe/conduit penetrations, duct openings)			
4	Exposed insulation at inverted roofs			
5	Loose or missing flashings, cladding components			
6	Debonded or damaged exterior sealants			
7	Other (specify)			
E – Other (specify)		**Yes**	**No**	**N/A**
1				
2				
3				
4				

Assessor Name: _____

Signature: _____

Position: _____

Date: _____

Structures Exposed To Aggressive Environments – **Type B Structures**

Owner Self-Performed Assessment Checklist

Date of Assessment					
Building Name					
Building Address					
Date of Construction	Year:				Unknown ☐
Last Maintenance	Year:				Unknown ☐
	If yes, describe work:				
Primary Structure Type	Cast-in-Place ☐	Precast ☐	Steel Framed ☐	Unknown ☐	Other (specify):
Post-Tensioned Construction	Yes ☐		No ☐		Unknown ☐
Structure Type	Above-Grade:		Below- Grade:		Other (specify):
Number of Levels	Suspended:		On- Grade:		
Exterior Ramp?	Yes ☐	No ☐	**Heated?**	Yes ☐	No ☐
Waterproofing System (Suspended Levels)	Traffic deck coating ☐	Protected membrane system (e.g. concrete topping) ☐	Asphalt overlay ☐	None (or none visible ☐	Unknown ☐ Other (specify):
Other Details					

Common Concerns In Higher Risk Structures & Maintenance Program Types

Item	Observation (Examples of Typical Deterioration)	Condition Present?		
A – Primary Structure		**Yes**	**No**	**N/A**
1	Active water seepage through cracks, structural joints, and expansion joints			
2	Staining or evidence of past water ingress (i.e. efflorescence*, debonded paint, stained insulation, damaged ceiling tiles)paint, stained insulation, damaged ceiling tiles)			
3	Water leakage through openings in the slab (i.e. unsealed pipe/conduit penetrations, duct openings)			
4	Spalled or delaminated concrete at slabs, columns, beams or walls			
5	Corrosion staining at underside of slabs, beams, surfaces of columns/walls			
6	Corrosion staining at steel beams/columns, connection plates, bolts, bearing pads, bracing, other structural steel components*			
7	Evidence of movement (cracking, spalling, separated joints, step-cracking in masonry walls*, etc.)			
8	Active water ingress through below-grade foundation walls			
9	Water collection at low points or clogged drains			
10	Water runoff over slab edges, through unprotected openings			
11	Other (specify)			
B – Secondary Structure		**Yes**	**No**	**N/A**
1	Damage, corrosion, or other deterioration at vehicle guardrails, perimeter upstand walls			
2	Damage, corrosion, or other deterioration within stairwells (i.e. stair landings, treads, handrails)			
3	Structures supporting mechanical equipment			
4	Overhead door framing			
5	Exterior Cladding			
6	Other (specify)			
C – Waterproofing Systems		**Yes**	**No**	**N/A**
1	Cracking, gouges, debonding, advanced wear of coating (polished surface, loss of aggregate)			
2	Debonded sealants			
3	Damage or debonded expansion joints*			
4	Other (specify)			

Common Concerns In Higher Risk Structures & Maintenance Program Types continued on next page

NOTE: Visual Examples included in Appendix D

Item	Observation (Examples of Typical Deterioration)	Condition Present?		
D – Mechanical and Electrical Systems		**Yes**	**No**	**N/A**
1	Snow melt system on ramps and slabs not functional or improperly functioning			
2	Sump frame and grate corrosion			
3	Trench and area drain frame and grate corrosion, debris accumulations			
4	Overhead door embedded detector loop wires and sealant debonding			
5	Damaged or corroded light fixtures or electrical conduits			
6	Other (specify)			
E – Building Envelope		**Yes**	**No**	**N/A**
1	Moisture ingress through stairwell roofs, glazing, doors			
2	Exposed insulation at inverted roofs			
3	Blisters, wrinkles, splits, punctures, low areas (ponding), gravel loss at conventional roofs			
4	Clogged, damaged, dented eavestroughs and downspouts			
5	Loose or missing flashings, cladding components			
6	Debonded or damaged exterior sealants			
7	Other (specify)			
F– Other		**Yes**	**No**	**N/A**
1	Damaged or displaced wheel stops			
2	Deterioration or damage of expansion joint			
3	Other (specify)			

Assessor Name: _____

Signature: _____

Position: _____

Date: _____

B

Post-Tensioned Structures Supplementary Information

Post-Tensioned Structures – Supplementary Information

Many structures in Calgary, in particular those built between the late 1960s and late 1980s utilized a style of construction know as post-tensioning. The high strength steel strands used in post-tensioned construction are susceptible to deterioration and strand breakage. Depending on the type of post-tensioning system, or moisture conditions to which the structure is exposed, the risk of deterioration can vary widely. Consequences of strand breakage range from a minor weakening of the structure, to posing a major structural concern and safety issue.

Post-tensioned buildings require a different approach to structural assessment when compare to other structures. Visual review by building Owners for signs of moisture ingress or tension loss is recommended, but visual indications of deterioration are often limited or non-existent. Owners should first understand how these systems work at a high level, to better engage with an engineer for assessment and maintenance. The most important factor an Owner has control over is understanding whether their building is post-tensioned or not. Knowing the nature of the building is critical to ensure an Engineering Professional can be engaged in a timely manner.

Most concrete slabs are reinforced with what is known as steel reinforcing bars, commonly referred to as "rebar". In post-tensioned slabs, the slabs are primarily reinforced with high strength steel strands, which are under tension.

NOTE: The terms "post-tensioned" and "post-tensioning" are sometimes used interchangeably. In this Guide, "Post-tensioned" describes the nature or state of the slab. "Post-tensioning" describes the reinforcing method itself.

Recognizing a Post-Tensioned Structure

There are visual cues that Owners can look for that indicate the presence of post-tensioning in a building. A few of these "tell tale signs" are outlined in the following Table.

Indicators Of Post-Tensioned Structures	
Live End Anchor Pockets	
At exposed post-tensioned slab edges, it may be possible to see the "live end" anchor pockets, which are the points the strands were originally stressed from. Typically these are circular in profile and filled with grout. However many slab edges are concealed by finishes such as cladding or flashing, and may not be visible. Below-grade slab edges will not be exposed.	
Eruption Plates	
In some cases, exposed slab edges may be equipped with eruption plates, also known as restraint plates, which are installed as a precaution against strand eruption from the slab edges in the event of a break or sudden tension loss. These will generally be galvanized steel plates equipped with concrete anchors to secure the plate to the slab edge. Typically they are located at slab edges at or near ground level where pedestrians may be present. They are not common at upper floor levels, or where the slab edge is concealed by cladding or other finishes.	
Staples	
For slabs that are exposed at their underside (not concealed by ceiling finishes), such as parking slabs or in back of house areas (mechanical rooms, electrical rooms, storage areas), it may be possible to see evidence of post-tensioning by looking for staples. Staples are used to secure the post-tensioned strand chairs to the formwork during original construction. When the formwork is removed, the legs of the staples project out of the concrete. **Note:** the two post-tensioned strands are visible at upper right side of photo (black plastic sheathing), exposed as part of an investigation	
Inspection Recess Plates	
Maybe the most common evidence of post-tensioning Owners can look for are inspection recess plates. When a building is assessed by an Engineering Professional, inspection recesses are usually chipped into the slab to expose short lengths of strands at different locations throughout the structure. The recesses allow the strands exposed within to be visually inspected and tested for tension, and re-accessed for future testing. The recesses are typically chipped at the underside of the slab where the strands are closest to the surface. After inspection, the recess cavity is filled with a mineral wool insulation and the recesses covered with an eruption plate, usually a square or rectangular galvanized steel plate. The plate is equipped with concrete anchors to secure the plate to the underside of the slab. These plates may not be visible at slabs concealed by ceiling finishes, but can usually be found in parkades or in back of house areas where the slabs are exposed.	

Post-Tensioning System Condition Assessments*

The nature and scope of any particular post-tensioning system assessment will depend on the building in question, and the Owner's own specific requirements. Buildings with an existing test sample and assessment history will differ from buildings that have not been previously assessed, or where records are unclear or inconsistent. Recommendations will also vary between Engineering Professionals based on their experiences.

Removal of concrete cover (by chipping/jackhammering taking care not to damage the strand) and visual inspection/tension testing of the exposed strand lengths is the most frequently used investigation method. The most common method used to assess strand tension is the "Penetration" test. This involves using a mallet to attempt to drive a flat head screwdriver into 6 perimeter wires of the 7 wire strand. Where the screwdriver is able to penetrate between the wires, this signifies a loss of tension in the strand. The degree of tension loss is correlated by the number of "penetrations" and the ease by which the screwdriver can be driven between the wires. The photograph on the side-bar is an example of this test being performed.

Strand Extraction

Where deemed applicable by the Engineering Professional, removal and full-length inspection of strands can yield additional information regarding the extent of moisture present in the system and the degree of strand corrosion. Moisture exposure at anchorages or at other locations along the strand length may not be detected at inspection recesses. It is also not possible to chip inspection recesses within the highly compressed anchor zone concrete, and therefore removal and inspection of strands may be the only means to identify if corrosion is occurring at the anchors. Usually only fully tension deficient (failed) strands are selected for extraction.

NOTE: This is for information only. Post-Tensioning System Condition Assessments are to be completed by an engineering professional.

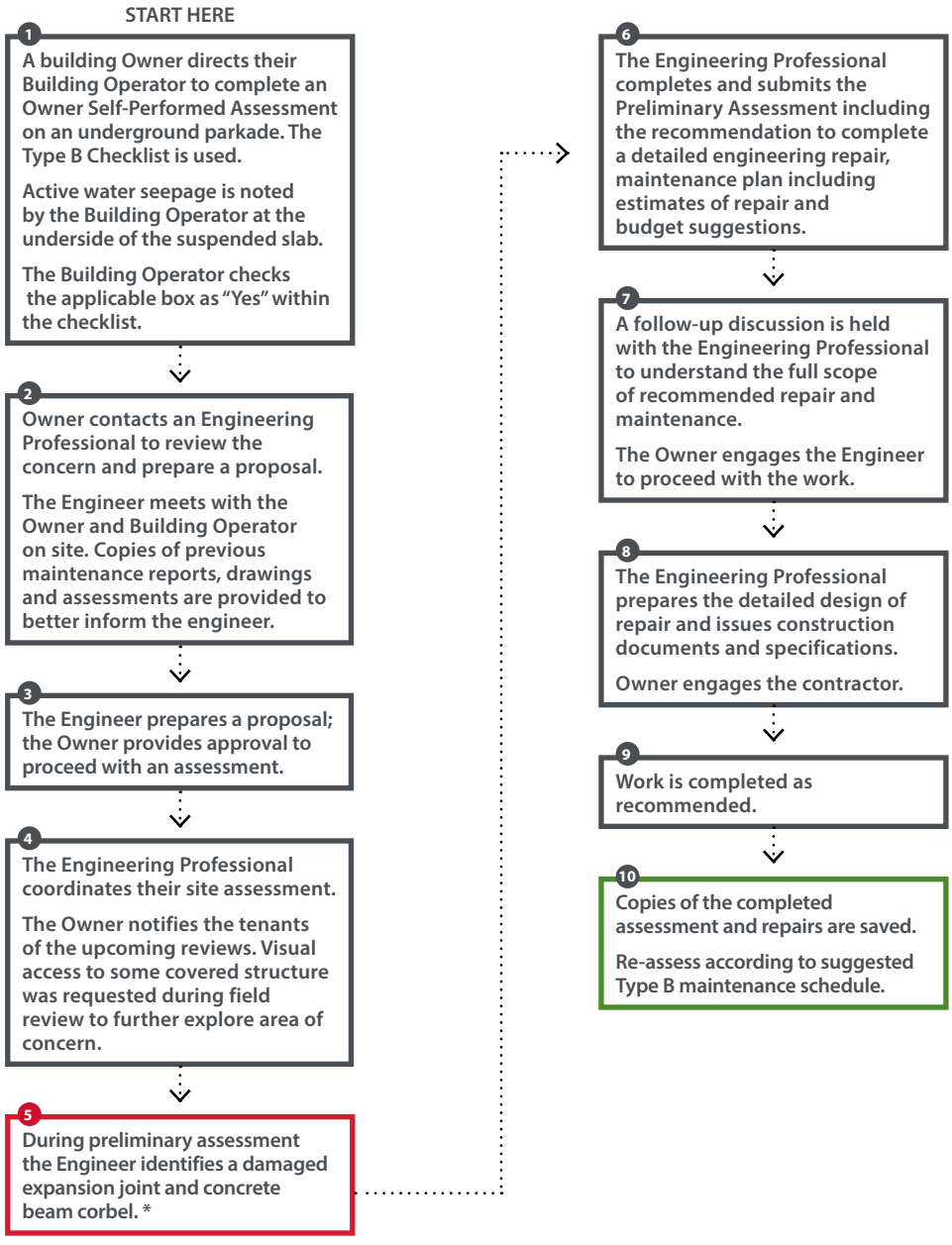
***NOTE:** Penetration test showing screwdriver wedged between wires of a post-tensioned strand. Note corrosion visible at the affected strand.

C

Alternate Assessment Process Charts

Assessment Process

Example 1: Professional Condition Assessment Process Type B - Parkade



Note: Repairs could be urgent or deferred based on Engineer discretion. Any un-safe conditions noted may require immediate action. Owner's are required to address unsafe conditions and follow Engineer's recommendations.

Example 2: Post-Tensioning System Assessment Process

START HERE

1. During a routine walk through, a building Owner identifies potential distress of their structure, including corrosion staining and evidence of moisture ingress at the underside of a parking deck slab.

   The Owner is aware from previous engineering reports that their building was constructed using a post-tensioning system.

2. Owner contacts an Engineering Professional to review the concern and prepare a proposal.

   The Engineer meets with the Owner and Building Operator on site. Copies of previous maintenance reports, drawings and assessments are provided to better inform the engineering services proposal.

3. The Engineer prepares a proposal; the Owner provides approval to proceed with an assessment.

4. The Engineering Professional coordinates a qualified post-tensioning system contractor on the Owner's behalf to assist with the testing.

   The Owner notifies their tenants of the upcoming work, and makes the work areas available (has vehicles removed from the parkade).

5. The Engineering Professional and contractor attend the site, access existing inspection recesses, open cover plates, and test the existing sample of post-tensioned strands.

   The Engineering Professional reviews the test data and confirms one of the post-tensioned strands in the sample is broken, having lost tension since the most recent test program. This indicates potential corrosion-related deterioration.*

   The Engineering Professional prepares a Post-Tensioning System Test report for the Owner.

6. The Owner reviews the report. A follow up discussion is held with the Engineering Professional to understand the full scope of recommended maintenance, costs, impact to the parking facility, impact to tenants, etc.

7. The Engineering Professional prepares the detailed design of repair and issues construction documents and specifications.

   Owner engages the contractor.

8. At the Owner's request, the Engineering Professional submits a proposal to prepare Contract documents, tender the work to Contractors, and provide Contract Administration and construction phase services.

   The full scope of work is approved.

9. Work is completed as recommended.

10. Copies of the completed assessment and repairs are saved.

    The Owner contacts the Engineering Professional before the next recommended post-tensioning system test date as outlined in their report, and the test process is repeated to compare and look for potential changes in strand tension.

Note: Repairs could be urgent or deferred based on Engineer discretion. Any un-safe conditions noted may require immediate action. Owner's are required to address unsafe conditions and follow Engineer's recommendations.

Professional Condition Assessment Report: Example Table of Contents

A typical professional condition assessment report would contain a table of contents similar to the following:

D

Definitions, Visual Examples & References

Definitions

Condensation: Process where water vapour contained in the air (gaseous form) becomes a liquid.

Delaminated Concrete: Separation concrete paste layer at the surface creating an unbonded layer from the primary concrete element.

Dew Point: Temperature below which water vapour condenses into liquid water. At the dew point temperature, relative humidity = 100%.

Efflorescence: Salt migration to surface of porous material causing a powder material to form.

Humidity: Amount of water vapour in the air. Water vapour is the gaseous state of water.

Relative Humidity (RH): Amount of water vapour in the air, expressed as a percentage to the greatest amount of water vapour possible (fully saturated) at the same temperature.

Step Cracking: Mortar cracks which appear in the shape of stair steps.

Visual Examples

Corrosion Staining



Damaged or Debonded Expansion Joints / Debonded Traffic Deck


Efflorescence


Spalled or Delaminated Concrete



Step Cracking (in masonry walls)


References

National Building Code – Alberta Edition
National Building Code of Canada:
Structural Commentary L - Application of NBC Part 4 of Division B for the Structural Evaluation and Upgrading of Existing Buildings

Professional Engineers of Ontario:
Structural Condition Assessments of Existing Buildings and Designated Structures

Engineers and Geoscientists British Columbia:
Professional Practice Guidelines – Structural Condition Assessment of Existing Buildings

ACI – American Concrete Institute:
ACI 201.1R-92 "Guide for Making a Condition Survey of Concrete in Service" ACI 224.1R-93 "Causes, Evaluation and Repair of Cracks in Concrete Structures"
ACI 362.2R-00 "Guide for Structural Maintenance of Parking Structures"

American Society of Civil Engineers:
ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings

Canadian Standards Association:
CSA S413:2 Parking Structures

National Research Council of Canada:
National Building Code, Commentary K, Application of Part 4 for the Structural Evaluation and Upgrading of Existing Buildings
Protocols for Building Condition Assessment, NRC – Institute for Research in Construction, Ottawa, September.
The Parking Garage Problem
Humidity in Canadian Buildings Indoor Swimming Pools

Canadian Parking Association:
Technical Bulletin No. 2: Parking Facility Maintenance Manual Technical Bulletin No. 6: Best Management Practices for Salt Use

FacilitiesNet:
How to Assess the Condition of Your Parking Structure (link)

Portland Cement Association:
Prevention of Concrete Scaling (link)

Building and Construction Authority (Singapore):
Periodic Structural Inspection of Existing Buildings - Guidelines for Structural Engineers

Canadian Wood Council:
Building Performance Bulletin: Moisture and Wood-Frame Buildings