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Unbonded Post-Tensioned Strand Structures: Strand Tension Monitoring – Recent Developments in Sampling and Monitoring Resulting in Remedial Repairs

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### **Read Jones Christoffersen Ltd.**

#### **Consulting Engineers**

• Offices in eight Canadian Cities

#### Core services:

- Structural Engineering
- Parking Planning
- Building Science
- Structural Restoration

Involved in evaluating, monitoring and repairing over 500 PT structures in Canada



## **Presentation Overview**

- Post-Tensioning System In High Rises
- Investigation
- Strand tension monitoring
- Structural repairs

#### **Structures Containing Unbonded Post-Tensioned Strands**





























# Different from conventionally reinforced concrete structures

- Evidence of Corrosion Commonly Hidden
- Methods of Evaluation Differ
- Selective Sampling and Interpretation

- Not practical to review entire PT system
- Need to be selective to limit risk
- Need to satisfy client requirements





#### **Visual Review**



#### Waterproofing Assessment



#### Sheathing Humidity Testing



## Acoustic Monitoring





ZONE ROOF NORTH



#### **PT Inspection Recesses**



#### **PT Inspection Recesses**



#### PT Inspection Recesses – Water In Sheathing



#### PT Inspection Recesses – Corrosion on Wires



#### **PT Inspection Recesses – Penetration Testing**



#### Location?

- Concentrate on high risk areas
- Spans adjacent to perimeters
- Low point of drape
- In areas of visual distress / moisture

## Vary size of recess to suit member

 Larger inspection recesses for banded group and beams vs. slab distributed groups



#### PT Inspection Recesses – Initial Investigation

From CMHC Protocol		
Building Size	Total Floor Area (sq. m)	Number of Strands in Sample
Single level	Less then 1,000	20
Single or multiple levels	Less than 3,000	60 to 80
High-rise (over 10 floors)	3,000 to 50,000	100
Multiple Tower or Large Building	Over 50,000	200
Critical members	Sample all members	

#### **Investigation Mandate 1985 to 1995**

# Random sampling

# Uniform moisture ingress assumed

# Strand tension deficiencies – global results

Statistics used to extrapolate sample results

# Initial testing concentrates on high risk areas

Further partition low-risk areas to include all floors of building

- Moisture exposure from construction differs between floors, even slab pours on same floor
- Service conditions differ isolated flooding, building envelope failures, damage due to renovation work











## **Expanded Sampling - Conclusions**

Need to determine condition of strands in areas not tested to date.

Increasing sample on all floors to expose approximately 5 to 10% of the total strands on each floor, representing different elements such as slab, banded/beam.

Continue to expand existing sample annually or in conjunction with regular tension testing of existing sample.

## **Investigation Mandate – Today**

Random sampling, however, partition sampling by moisture risk

Sampling extend to all floors and areas

Variable moisture assumed

Strand tension deficiencies considered for structural impact on immediate vicinity (no global treatment)

Results of tension testing and visual used to help determine condition of PT system

Sample of strands tested regularly

- 6 month intervals high risk, changes
- Annually standard
- Every 2 years low risk, no changes

Regular tension monitoring used to:

- Establish long term condition of PT system
- Detects changes in tension, from previous testing event
- Focus investigations into the PT system condition in areas of changes in tension or moisture ingress

Expose and tension test all strands at inspection recess in member or bay before performing structural analysis

Analyze using design live load, do not reduce

 Change live load occupancy in future for filing systems, computer servers, etc. for which a load review will be based on drawings and referenced live loads

Owner may wish to replace all tension deficient strands

## **Further Investigation Sampling**

Full Length Extraction of Strand for Visual Review

- Confirm moisture access and extent (if any)
- Provides indication of how tension deficiency occurred and where



#### Centre stressing common

Replace full length of strand, need access to slab edges and remove intermediate anchors

Splicing should be avoided

- •Use only if cannot practically replace full strand length (strand runs through column)
- •Existing strand lengths to be free of moisture and corrosion
- •Stress with caution













## **Structural Steel Sub-Frame**



















# Older unbonded PT systems susceptible to moisture ingress

Investigation required to determine condition and reduce risk

Various techniques available to investigate, inspection recesses most important

Regular monitoring of strand tension and moisture exposure



Use information from strand sample tension, including changes in tension detected during monitoring to focus investigation

Various repair methods available to address strand tension loss

# THANK YOU