Emerging Technologies

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The Dig Down below Toronto Union Station
80 year old Concrete Augmented with Modern Technology
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CONTENT

1. History of Union Station
2. The Revitalization Project
3. Column replacement approach
4. Monitoring of column replacement
5. Concrete material technologies
6. Remaining columns strengthening
7. Other interventions

1. HISTORY OF UNION STATION
1.1 THE HEAD HOUSE

• Head House completed by 1919
• Hybrid of steel frame and masonry
• Concrete slabs with encased steel at & below grade
• Terracotta flat arches on steel framing above grade

1.2 THE VIADUCT STRUCTURE

• Viaduct structure by end of 1920’s
• Concrete substructure and suspended slab
1. HISTORY OF UNION STATION

1.3 THE TURNER FLAT SLAB

- Four-way system of reinforcement with bent bars
- Mushroom columns with drop panels

2. THE REVITALIZATION PROJECT

2.1 MAIN OBJECTIVES

- Enlarge concourse of busiest train station in Canada
- Create new commercial and food outlets
- Conserve one of Canada’s most significant heritage sites

2.2 THE CONCEPT

- An area of 25,000 sqm (270,000 sqf) is dig down
- The dig-down ranges from 3 to 3.8 m
- Will roughly match elevation of TTC concourse

- Section through the station before dig down

- Column replacement concept
2. THE REVITALIZATION PROJECT

2.3 THE UNDER-UTILIZED BASEMENT

Basement was used for parking, car rentals and only partially for station activities.

3. COLUMN REPLACEMENT

3.1 PLANNED SEQUENCE OF CONSTRUCTION

3.2 ARCHITECTURAL CONCEPT

3.3 CONSTRUCTION

Slab on grade is removed and site is excavated to bedrock to remove all unsuitable fill.

3. COLUMN REPLACEMENT

3.3 CONSTRUCTION

Micropiles are used to support the HSS shoring system.

3. COLUMN REPLACEMENT

3.3 CONSTRUCTION

Jacks are placed at top of telescopic shoring posts. Manifold used to ensure equal pressure at 4 jacks.
3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

With jacking process completed, the telescopic shores are welded in place and jacks removed.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

Once shored the existing column is cut, the pedestal removed and the rebars are prepared for coupling.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

Mechanical couplers are installed in a staggered pattern to splice the new rebars to the round ones.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

New columns are formed, ready to pump SSC from the base. Grouting the last 50 mm follows.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

Extended columns show dowels used to splice to drop panel rebars prior to casting suspended slab.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

Formwork and scaffolding prepared for casting the concourse slab.
3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

Lower retail space prior to casting the slab on grade

New upper concourse showing track slab, existing drop panels and column mushroom capitals

Hub room slab on micropiles to support track equipment. Couplers used to connect to new slab.

4. MONITORING COLUMN REPLACEMENT

• Robotic total-station
• Monitoring during load transfer and beyond
  • 0.3 mm accuracy
  • 6 mm tolerance

4. MONITORING COLUMN REPLACEMENT

Theoretical and actual movement of column

5. CONCRETE MATERIAL TECHNOLOGIES
5.1 MAIN ENCOUNTERED CONDITIONS

• Column replacement
  - two stage cast
  - 1st pour early strength low shrinkage
  - 2nd pour 50 mm grout with ES and LS
• Column jacketing
• Repair of spalled and delaminating concrete
• Carbonated concrete
5. CONCRETE MATERIAL TECHNOLOGIES

5.2 EXISTING CONCRETE STRENGTH

- Assumed strength of columns is 25 MPa
- Tested concrete is higher than specified strength of 1.5 and 2 ksi assumed for lower and upper part of pedestals respectively
- Significant variability in the core testing
- The concept of CFRP could not be applied to the weak unreinforced concrete pedestals

5.3 MIX DESIGN SPECIFICATION

- Constraints on Mix Design
  - Congestion of the reinforcement at splice
  - Need to pump from the base of the column
  - Vibration not practical
  - Limited access to the basement site
  - Early strength required for replacing over 200 columns on site almost sequentially
  - Shrinkage must be limited as casting is done between two set points to transfer load

5.4 MIX DESIGN – Self Consolidating Concrete

- High Range Water Reducing Admixture
- Euclid Chemical admixture: PLASTOL 5000
- Polycarboxylate based
- Increases early concrete strength as well as ultimate strength.

- Other admixtures such as Plastol 341 and Eucon WR have also been used.

5.4 MIX DESIGN – Shrinkage Reduction

- ShrinkGuard™ is a ST MARYS CBM Shrinkage Reducing Admixture used to limit shrinkage by as much as 50% and is based on Eclipse® technology.
- Eclipse® 4500 from Grace is a liquid admixture that dramatically reduces drying shrinkage. Rather than functioning as an expansive agent, Eclipse 4500 acts by reducing the surface tension of pore water
5. CONCRETE MATERIAL TECHNOLOGIES

5.5 EARLY STRENGTH GAIN FOR COLUMNS

- 50% Day 7
- Linear (7/28 Day ft)

60% consistently achieved. Average rose to almost 80%

5. CONCRETE MATERIAL TECHNOLOGIES

5.6 EARLY STRENGTH RESULTS

- 7 Day ft (MPa)
- Linear (7 Day ft (MPa))

35 MPa is specified at 7 days to allow early load transfer

5. CONCRETE MATERIAL TECHNOLOGIES

5.7 GROUT – Second Pour

- SikaGrout 212 HP
- High-performance cementitious grout with silica fume
- Two-stage shrinkage compensating mechanism in both the plastic and hardened states
- Placed at various consistencies ranging from flowable to fluid

6. REMAINING COLUMNS STRENGTHENING

6.1 COLUMN JACKETING

Reinforcement for jackets as well as shear dowels are in place to cast column jackets in VIA area.

6. REMAINING COLUMNS STRENGTHENING

6.2 CARBON FIBRE REINFORCED POLYMER (CFRP)

Some completed jackets and a pedestal with only the shear dowels.

Shop drawings for carbon fibre details for VIA columns. CFRP layers and anchors are used.
6. REMAINING COLUMNS STRENGTHENING
6.2 CARBON FIBRE REINFORCED POLYMER (CFRP)

Applied carbon fibre viewed from the lower retail level. Concrete jackets are planned for pedestals.

7. OTHER INTERVENTIONS
7.1 WIDENING OF MALL

7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

Storey-high loading dock transfer trusses are erected in order to remove one line of columns.

7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

Two trusses per column take up its load. Jacks are placed on top of trusses to transfer load.

7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

Column is wire cut at the underside of its capital. The column and pedestal are then segmentally removed.
7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

Shown are the remaining column capital, trusses, their lateral restrain and a monitoring target.

7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

Loading dock double width bay is created by the removal of a line of existing columns.

7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

Trusses in the upper concourse over the new loading dock will be enclosed within partitions.

QUESTION TIME