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Emerging Technologies

ACI Fall 2012 Convention
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ACI WEB SESSIONS

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

by

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80 year old Concrete Augmented with Modern Technology

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Scott Norris, P.Eng.

CONTENT

FALL 2012 CONVENTION TORONTO
UNION STATION DIG DOWN

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1. HISTORY OF UNION STATION
1.1 THE HEAD HOUSE

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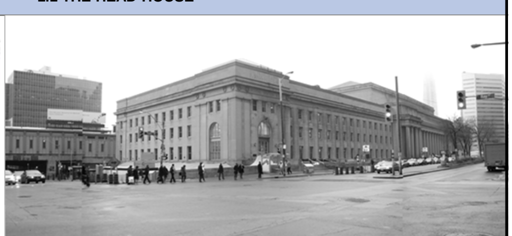
UNION STATION DIG DOWN



- 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

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1. HISTORY OF UNION STATION
1.2 THE VIADUCT STRUCTURE

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- Viaduct structure by end of 1920's
- Concrete substructure and suspended slab

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1. HISTORY OF UNION STATION
1.3 THE TURNER FLAT SLAB

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

2. THE REVITALIZATION PROJECT
2.1 MAIN OBJECTIVES

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

2. THE REVITALIZATION PROJECT
2.2 THE CONCEPT

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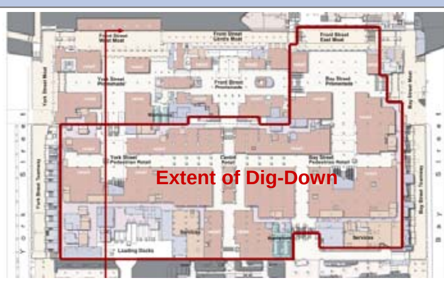
UNION STATION DIG DOWN



- 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

2. THE REVITALIZATION PROJECT
2.2 THE CONCEPT

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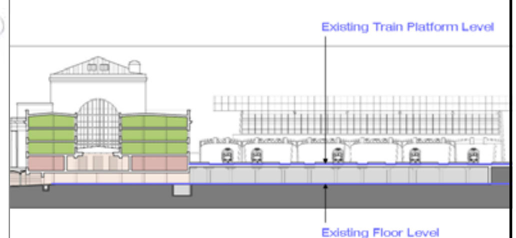
UNION STATION DIG DOWN



- Section through the station before dig down

2. THE REVITALIZATION PROJECT
2.2 THE CONCEPT

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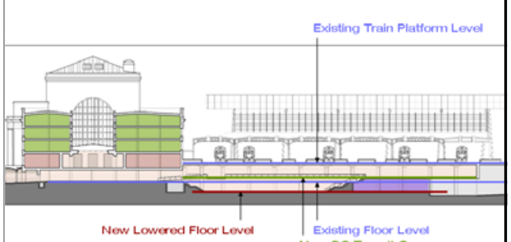
UNION STATION DIG DOWN



- Section through the station after dig down

2. THE REVITALIZATION PROJECT
2.2 THE CONCEPT

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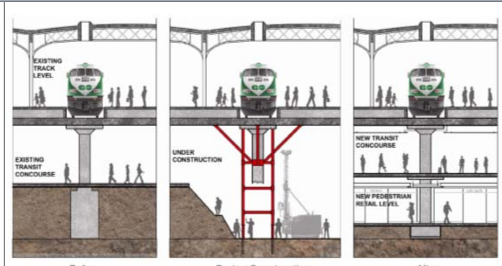
UNION STATION DIG DOWN



- Column replacement concept

2. THE REVITALIZATION PROJECT
2.3 THE UNDER-UTILZED BASEMENT

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

3. COLUMN REPLACEMENT
3.1 PLANNED SEQUENCE OF CONSTRUCTION

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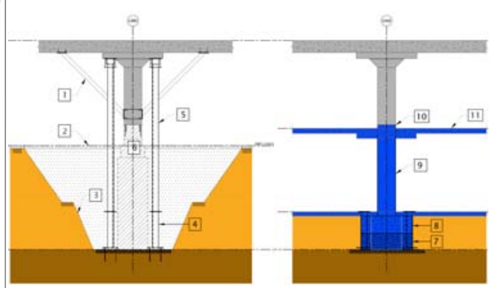

3. COLUMN REPLACEMENT
3.2 ARCHITECTURAL CONCEPT

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3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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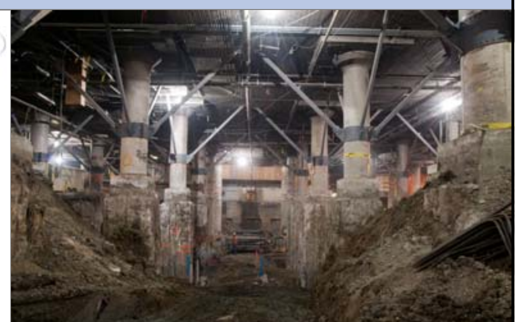

Slab on grade is removed and site is excavated to bedrock to remove all unsuitable fill.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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Micropiles are used to support the HSS shoring system.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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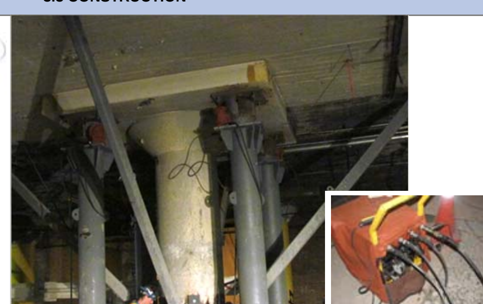

Jacks are placed at top of telescopic shoring posts. Manifold used to ensure equal pressure at 4 jacks.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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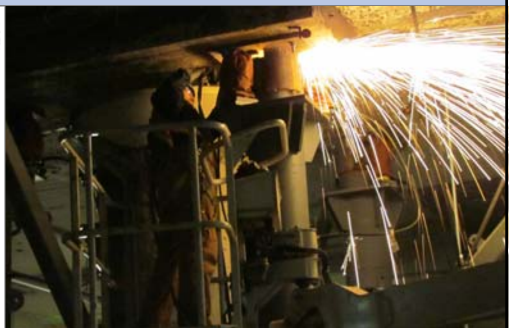

With jacking process completed, the telescopic shores are welded in place and jacks removed.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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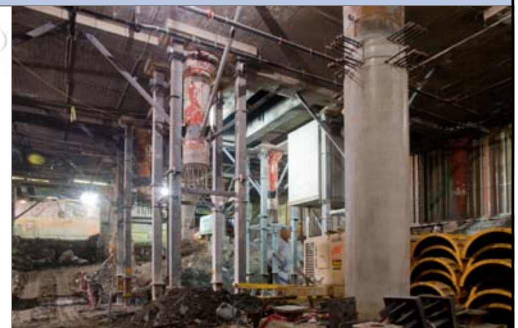

Once shored the existing column is cut, the pedestal removed and the rebars are prepared for coupling.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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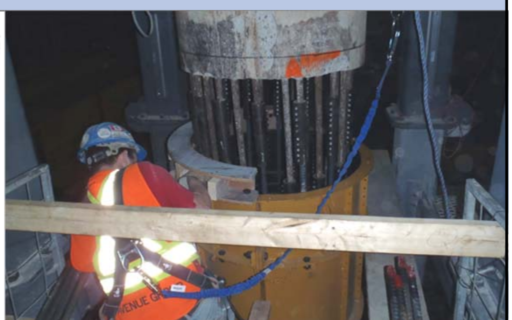

Mechanical couplers are installed in a staggered pattern to splice the new rebars to the round ones.

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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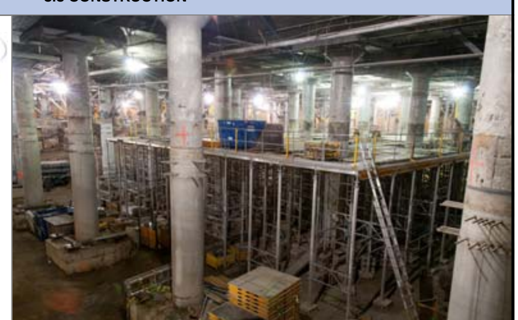

Formwork and scaffolding prepared for casting the concourse slab

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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Lower retail space prior to casting the slab on grade

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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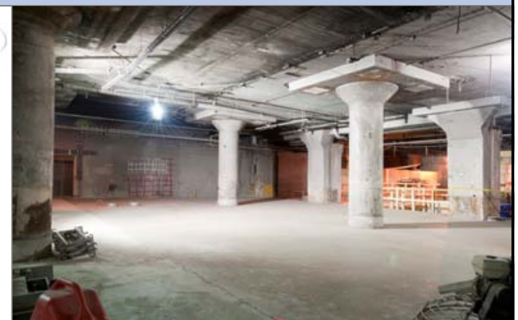
UNION STATION DIG DOWN



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

3. COLUMN REPLACEMENT
3.3 CONSTRUCTION

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

4. MONITORING COLUMN REPLACEMENT

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

4. MONITORING COLUMN REPLACEMENT

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Theoretical and actual movement of column

5. CONCRETE MATERIAL TECHNOLOGIES
5.1 MAIN ENCOUNTERED CONDITIONS

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- 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

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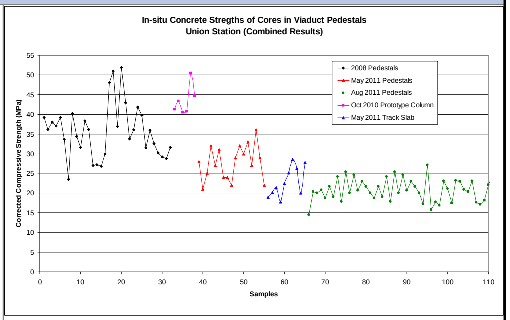
UNION STATION DIG DOWN



Testing before and during the dig down

5. CONCRETE MATERIAL TECHNOLOGIES
5.2 EXISTING CONCRETE STRENGTH

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- 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. CONCRETE MATERIAL TECHNOLOGIES
5.3 MIX DESIGN SPECIFICATION

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UNION STATION DIG DOWN

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. CONCRETE MATERIAL TECHNOLOGIES
5.3 MIX DESIGN SPECIFICATION

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UNION STATION DIG DOWN

Mix Design Criteria for Column Concrete

- Flowable SCC for pumping and eliminating need for vibration
- ShrinkGuard^{TM} to reduce shrinkage
- 7 day strength of 35 MPa. Use of cement rich mix with WR admixture
- Maximum aggregate size is 10 mm
- Use of high range water reducing admixtures

5. CONCRETE MATERIAL TECHNOLOGIES
5.4 MIX DESIGN – Self Consolidating Concrete

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- 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. CONCRETE MATERIAL TECHNOLOGIES
5.4 MIX DESIGN – Shrinkage Reduction

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UNION STATION DIG DOWN

- **ShrinkGuard^{TM}** 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

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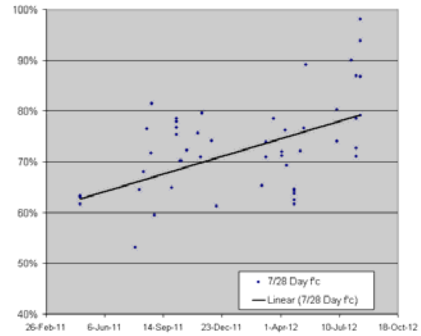

60% consistently achieved. Average rose to almost 80%

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5. CONCRETE MATERIAL TECHNOLOGIES
5.6 EARLY STRENGTH RESULTS

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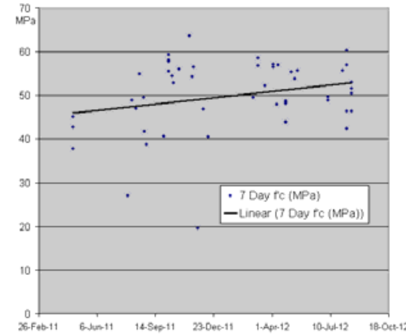
UNION STATION **DIG DOWN**



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

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5. CONCRETE MATERIAL TECHNOLOGIES
5.7 Grout – Second Pour

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UNION STATION **DIG DOWN**

- **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**

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6. REMAINING COLUMNS STRENGTHENING
6.1 COLUMN JACKETING

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

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6. REMAINING COLUMNS STRENGTHENING
6.1 COLUMN JACKETING

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UNION STATION **DIG DOWN**

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

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6. REMAINING COLUMNS STRENGTHENING
6.2 CARBON FIBRE REINFORCED POLYMER (CFRP)

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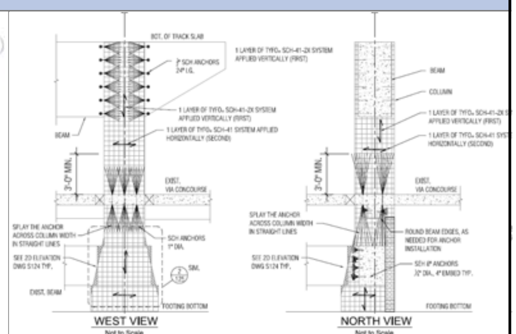

Shop drawings for carbon fibre details for VIA columns. CFRP layers and anchors are used.

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6. REMAINING COLUMNS STRENGTHENING
6.2 CARBON FIBRE REINFORCED POLYMER (CFRP)

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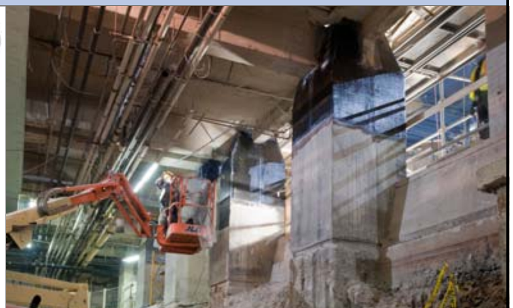

Applied carbon fibre viewed from the lower retail level. Concrete jackets are planned for pedestals.

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7. OTHER INTERVENTIONS
7.1 WIDENING OF MALL

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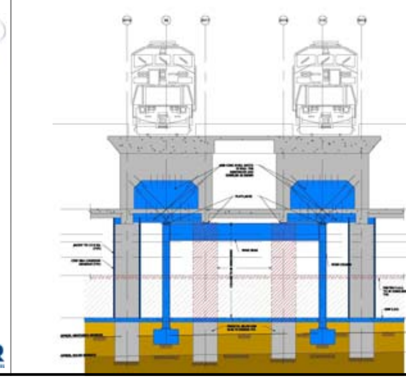

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7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

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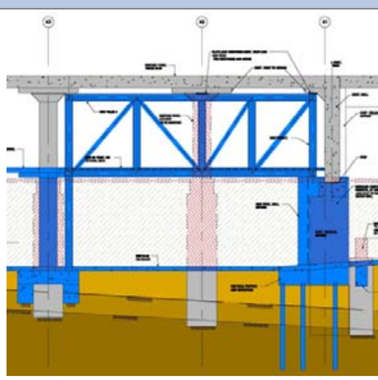

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7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

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

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7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

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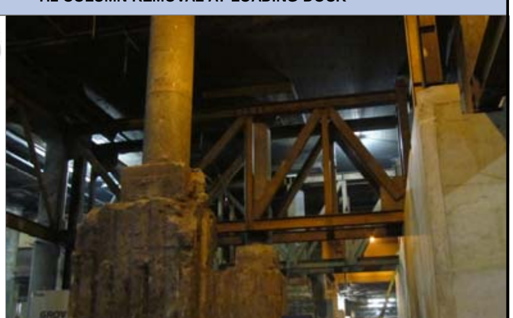

Two trusses per column take up its load. Jacks are placed on top of trusses to transfer load.

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7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

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Column is wire cut at the underside of its capital. The column and pedestal are then segmentally removed.

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7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

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

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7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

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

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7. OTHER INTERVENTIONS
7.2 COLUMN REMOVAL AT LOADING DOCK

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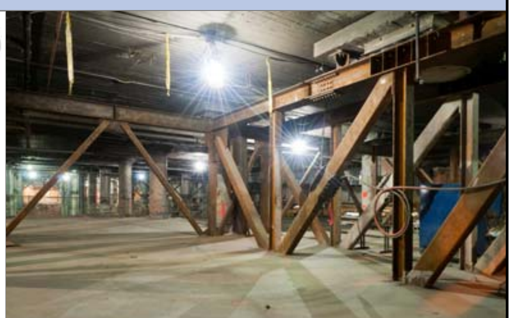

Trusses in the upper concourse over the new loading dock will be enclosed within partitions.

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QUESTION TIME

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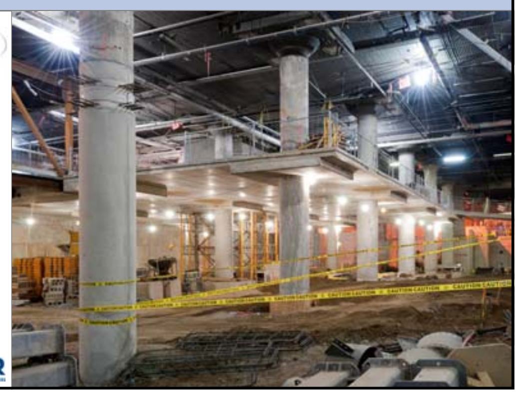

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