**BCBEC Luncheon**
**June 14, 2012**

# "Integral Waterproofing"

**Presented by**

**Joel Schwartz, P.Eng, FEC, BEP**

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# Background

Case study of two large high-rise projects at False Creek in Vancouver, BC


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# Case Study 1: Site Parameters

- ✓ Below-grade portion 20 feet below water table
- ✓ 1250 psf (62.5 kPa) constant water pressure
- ✓ Sheet piling complicated or eliminated typical waterproofing solutions *(positive or negative side)*
- ✓ Blind-side application required
- ✓ Old industrial lands; largely remediated soils

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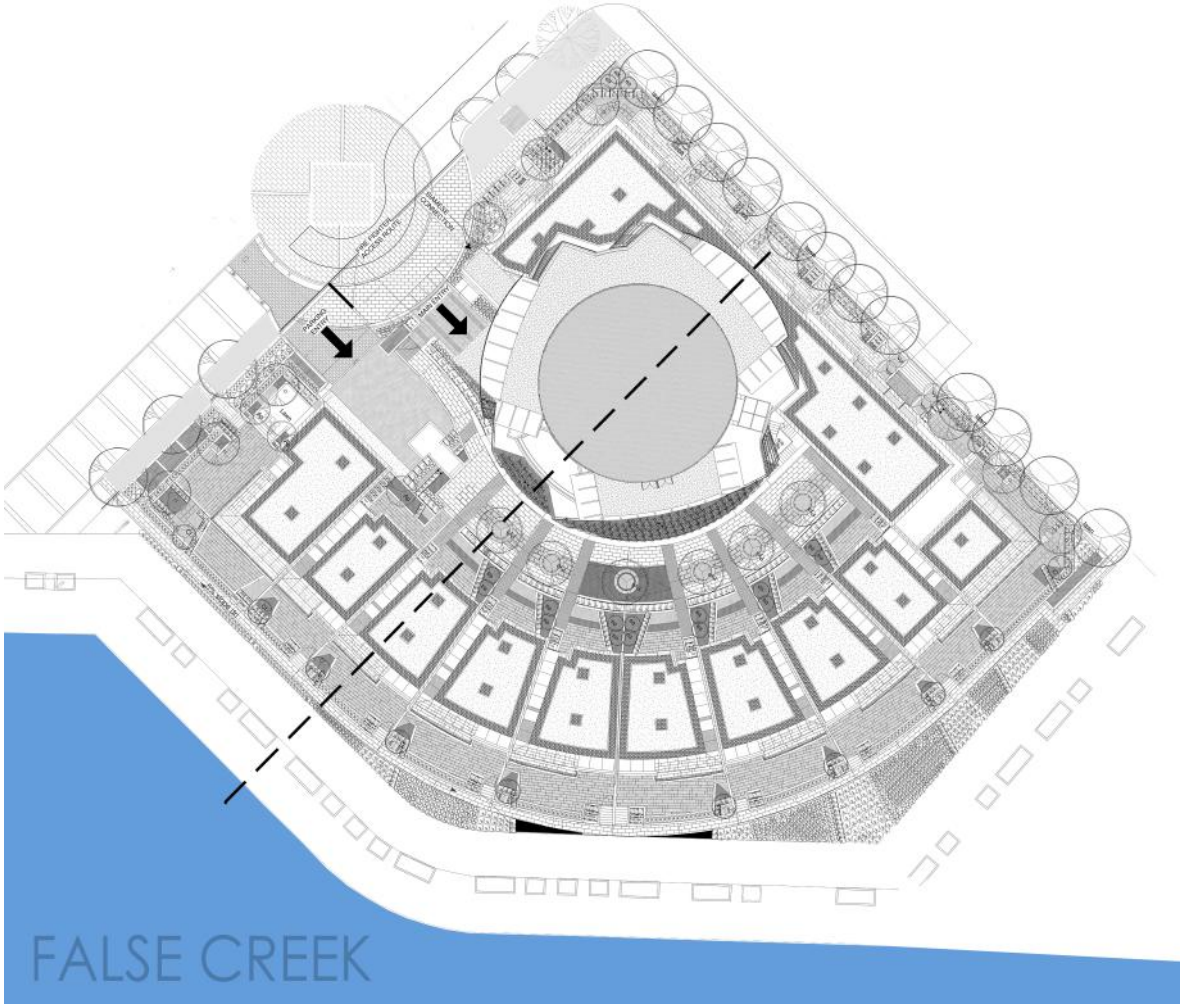
# Case Study 1: Site Plan

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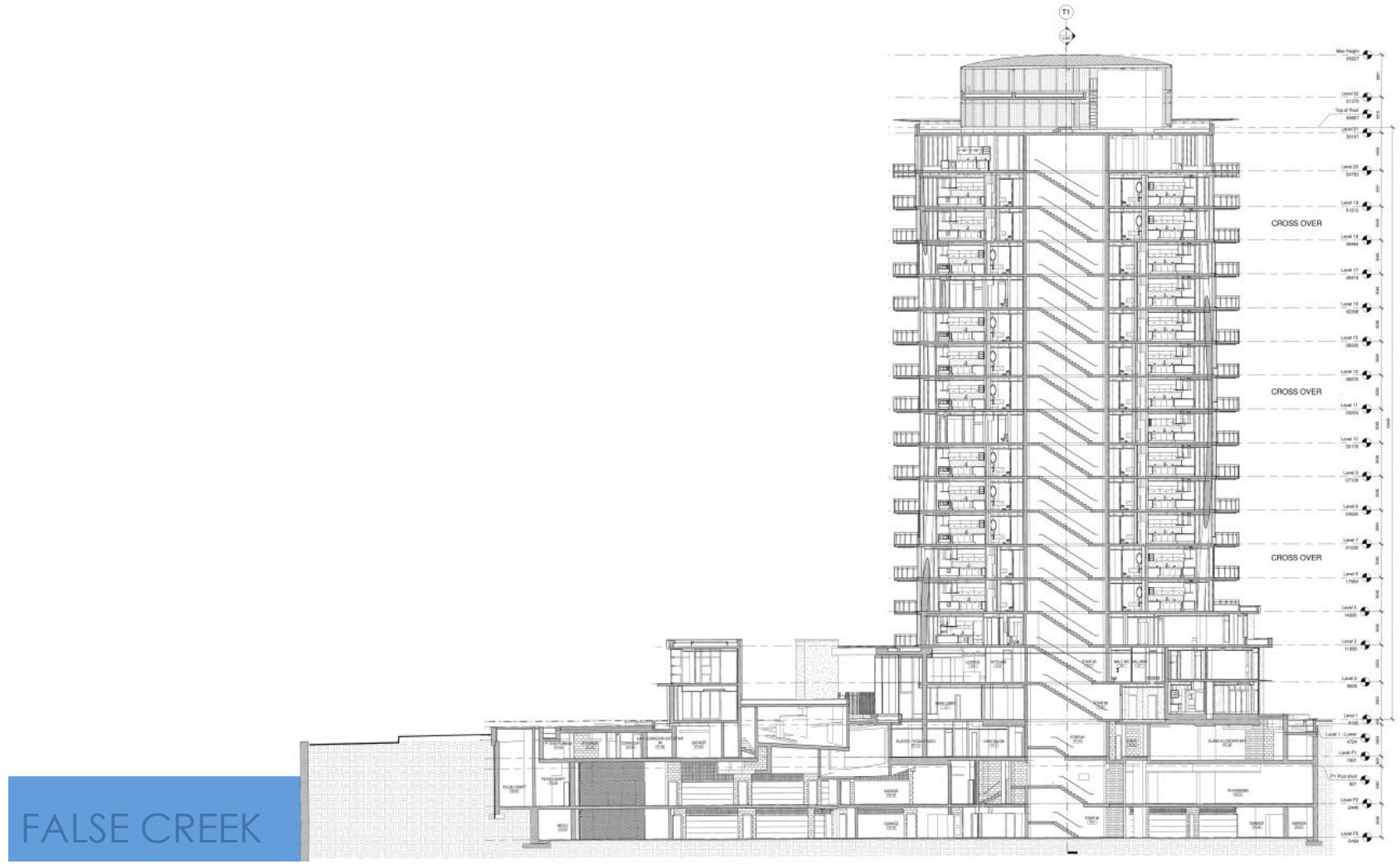
# Case Study 1: Site Section

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# Case Study 1: Site Photo

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# Case Study 2: Site Parameters

- ✓ Below-grade portion 33 feet below water table
- ✓ 2000 psf (100 kPa) constant water pressure
- ✓ Sheet piling complicated or eliminated typical waterproofing solutions *(positive or negative side)*
- ✓ Blind-side application required
- ✓ Old industrial lands; largely remediated soils

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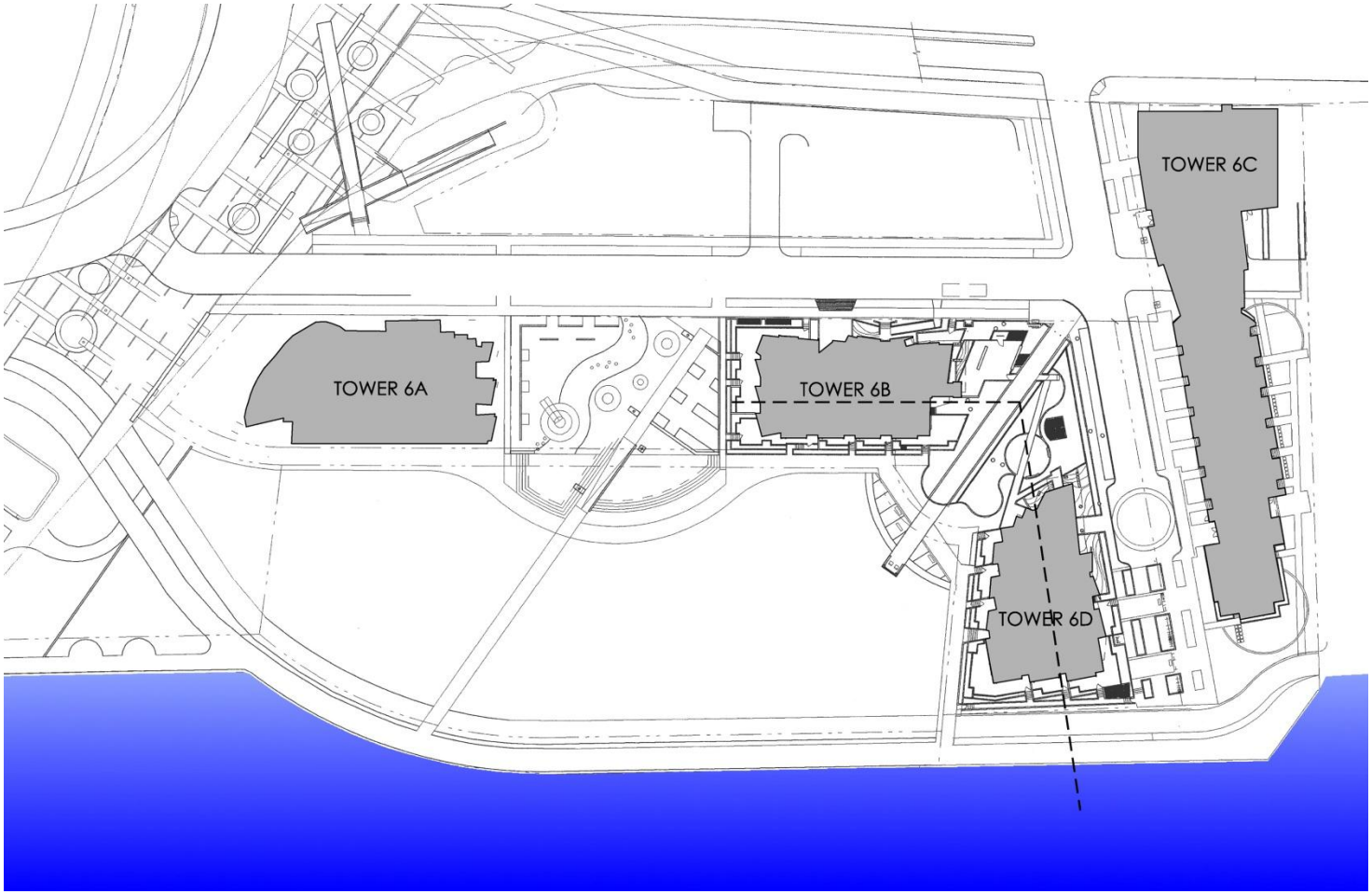
# Case Study 2: Site Plan

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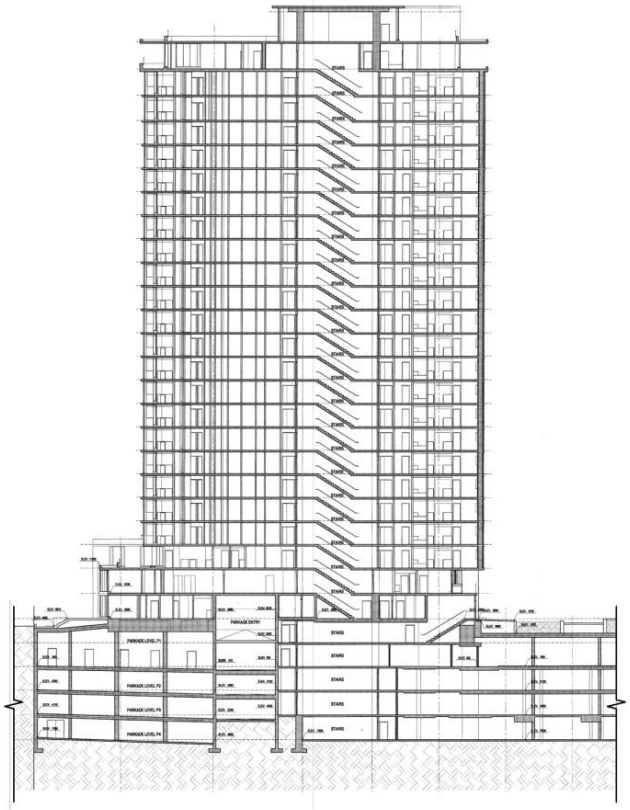
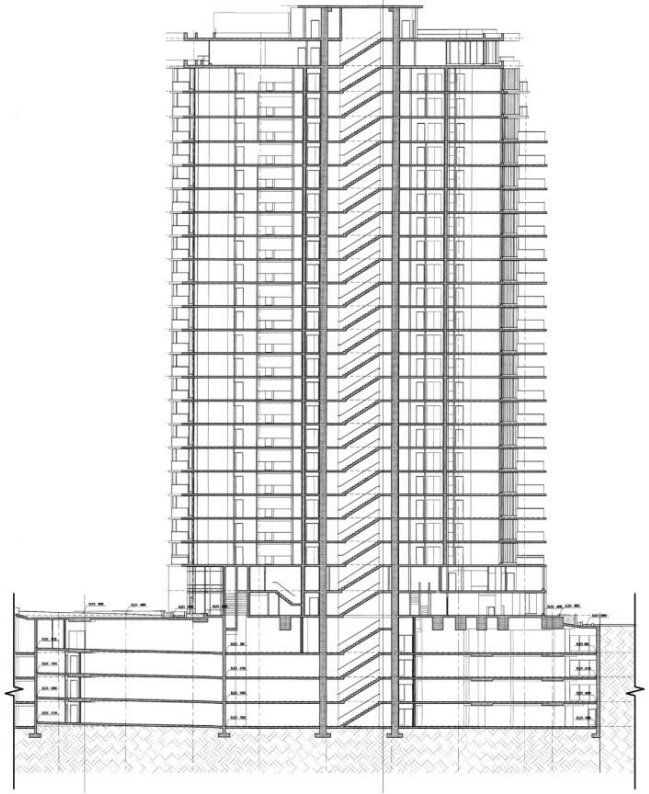
# Case Study 2: Site Section



TOWER 6B



TOWER 6D

FALSE CREEK

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# Case Study 2: Site Photo

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# Systems Considered

- ✓ JRS participated early in design, evaluating potential systems:
  - Sheet Membranes
  - Spray-Applied Liquid
  - Concrete Admixture

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# Challenges

- ✓ Performance requirements
- ✓ Client's mixed experience with sheet membranes in blind-side applications
- ✓ Applicability of spray-applied liquid for site conditions questionable; little history of use in similar applications
- ✓ Data on concrete admixture was reassuring, but required further research into real-case applications before using for such a large-scale project

# Integral WP Basics

- ✓ Reacts with water and un-hydrated cement particles, forming microscopic, needle-like crystals
- ✓ Crystals fill pores and microscopic voids in concrete, blocking pathways for water and contaminants
- ✓ Water re-entering through changing pressure or fresh cracks triggers crystal growth, which seals the concrete to re-establish water tightness

# Evaluation: System Pros & Cons

| Sheet Membrane | |
|---|---|
| **Pros** | **Cons** |
| • Consistent membrane thickness<br>• Barrier system prevents moisture contact with structure | • Higher in-place costs (materials + labour)<br>• Requires careful surface preparation and detailing (seams & penetrations)<br>• Can't easily be applied to steel formwork.<br>• Certain details can not be waterproofed with system (form ties)<br>• Subject to damage and contamination during concrete pour (cannot be inspected or reviewed)<br>• Repairing leakage through concrete would require chipping away membrane and packing with crystalline grout or epoxy / urethane injection.<br>• Repair methodology inconsistent with base waterproofing strategy |

# Evaluation: System Pros & Cons

| Spray-Applied Liquid | |
|---|---|
| **Pros** | **Cons** |
| • Can be applied to “green” concrete<br>• Quick application<br>• Low in-place cost (materials + labour)<br>• Barrier system prevents moisture contact with structure | • More commonly applied conventionally (over-excavation)<br>• Blind-side application typically applied to drain mat or shotcrete<br>• Membrane thickness can be inconsistent<br>• May not be as tough and resilient as other systems<br>• Not enough performance data on similar applications<br>• Water based systems can be susceptible to constant moisture while curing |

# Evaluation: System Pros & Cons

| Concrete Admixture and Joint Treatment | |
|---|---|
| **Pros** | **Cons** |
| • No separate waterproofing membrane required—concrete becomes waterproofing system<br>• Offers labour and time savings compared to other waterproofing methods<br>• Self-seals cracks from curing and settling of concrete<br>• Can be repaired from interior<br>• Repair methodology consistent with base waterproofing strategy | • Must be extra diligent to prevent contamination by foreign items / contaminants in open formwork<br>• Product mixes must be carefully controlled to meet location / performance requirements<br>• Requires careful and thorough coordination of structural and materials consultant<br>• Requires water flow to activate crystals. May not be appropriate for areas where any initial leakage is not acceptable<br>• System vulnerabilities at control and construction joints |

# Warranty Considerations

***"A Warranty has never kept water out of a building"***

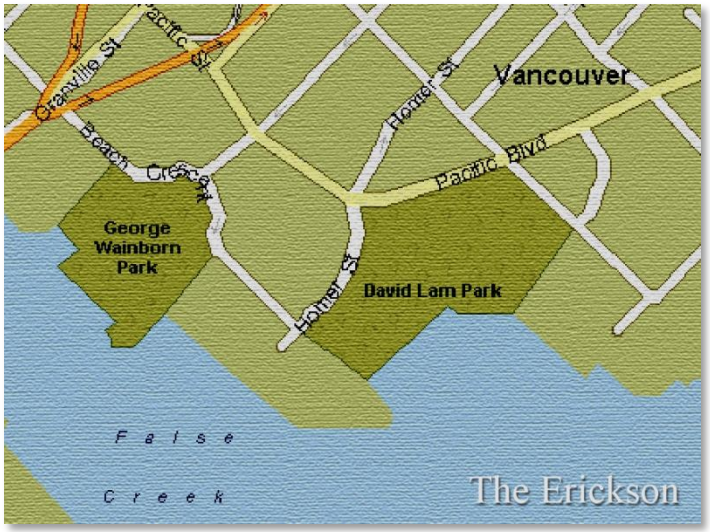
- ✓ Most product warranties are primarily marketing tools—quite limited, with numerous exclusions & fine print
- ✓ JRS found that admixture manufacturer's warranty had substance. It was performance-based and dependant on manufacturer's involvement in the design and planning, with specific quality control processes.

# Warranty Considerations

- ✓ Warranty was based on entire quality process to drive final quality:
  - Manufacturer review & acceptance of concrete mix design
  - Manufacturer review of structural design *(joint spacing, joint design, steel ratios)*
  - Documented quality control system to track product batches from plant to site, ensuring product would be installed *(placed)* at correct locations in correct amounts.
  - Manufacturer provided additional 3rd party review of the preparation of all areas. *(JRS provided the supplementary reviews with agreement of client and manufacturer)*

# Research

- ✓ Large project with major risk implications; demanded due diligence prior to acceptance
- ✓ Lack of similar applications in lower mainland
- ✓ Reviewed nearest matches:
  - Shaw Tower; only 5 ft. below water table
  - Reviewed shotcrete application in Gastown; however, limited depth below water table and concrete system entirely different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# Research

- ✓ Similar Project Requirements
  - Comparable water pressure
  - Good and available records
  - Completed with in-service history
  - Access to design and construction team members
  - Access to operations/facility manager

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# Research: Similar Projects

- ✓ Identified three most similar projects finished to date:
  - Orlando Airport Expansion Tunnel, Orlando, FL, USA
  - Ballyliffin, Tara, and Jacksons Hotels, Dublin, Ireland
  - UnderWaterWorld, near Brisbane, Australia

# Research: Similar Projects

- ✓ Contacted and interviewed key members involved with the project to discuss their experience using the admixture.
  - Design team members: design implications and considerations, professional concerns and liability issues.
  - Construction team members: construction and practicality issues.
  - Facility operations & maintenance personnel: in-service (post-construction) performance experiences.

# Orlando Airport Expansion Tunnel

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# Ballyliffin, Tara & Jacksons Hotels

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# UnderWaterWorld


# Roles

- ✓ Architect designed and took responsibility for overall design and systems other than below-grade
- ✓ JRS was project building envelope consultant, but assumed additional role and took responsibility for design of below-grade waterproofing
- ✓ General contractor responsible for overall work
- ✓ Forming sub-contractor responsible for system preparation (joint detailing) and overall quality control
- ✓ JRS had responsibility for quality assurance; actual role fell in between quality control and quality assurance

# Design

- ✓ Because this was a new system, JRS was asked to take professional responsibility for design and quality control for system throughout project
- ✓ Design details started as manufacturer's standard details, evolving into site-specific details.
- ✓ Had to accommodate for admixture weakness at cold joints and control joints.

# Design



1.1 Inspection

.1 The installation shall be inspected in two stages:

.1 Following the installation of the Grout strip, an inspector shall visually inspect the installation to confirm the presence and location of the "red" triangular strip in the proper dimensions.

.2 Following the installation of the Treatment slurry, an inspector shall visually inspect the installation to confirm the presence and location of the "gold" strip which shall cover the entire contact area of the joint.

.2 If it is not possible to inspect the installation in two stages, then a single inspection can be made after the completion of the installation of both products. The inspector shall confirm the presence and location of the "gold" strip which shall cover the entire contact area of the joint. At or near the center of the gold strip shall be a raised triangular section of the proper dimensions. If necessary, a small section of the "gold" Treatment may be removed from the triangle portion of the strip to reveal the "red" Grout beneath.

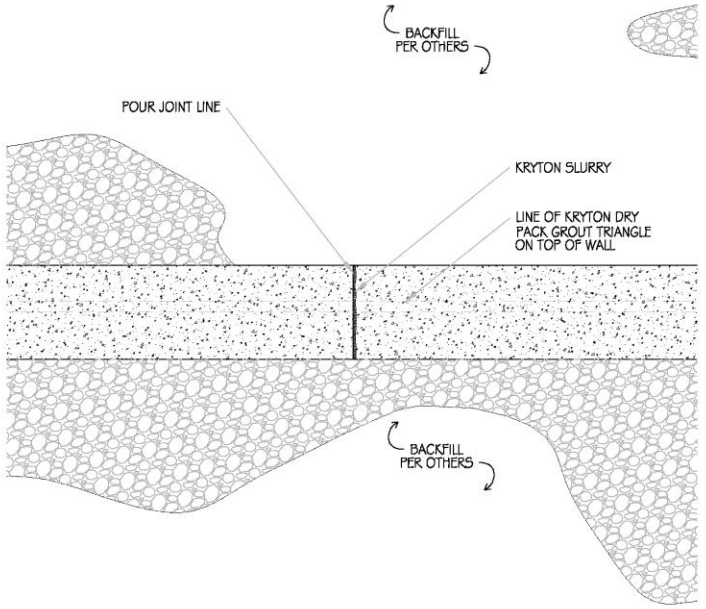
.3 Inspection of the joint treatment shall occur prior to installation of interior formwork.

.4 Inspection of the form-tie waterproofing and external waterstop shall occur prior to application of any finishes.

END OF SECTION

LEGEND

- CONCRETE
- CONCRETE w. KIM ADMIXTURE
- KRYTON DRY-GROUT WATERSTOP
- KRYTON SLURRY
- KRYSTOL EXTERNAL DRY-GROUT WATERSTOP
- BARICOTE (FORM TIE PLUG)
- KRYSTOL PLUG




NOTE: DO NOT SCALE FROM DRAWING. ALL DIMENSIONS TO BE OBTAINED AND VERIFIED ON SITE.

NOTES:
1. DRAWING PROVIDED TO SHOW PRIMARY STRUCTURE WATERPROOFING DETAILS. REFER TO ARCHITECTURAL AND STRUCTURAL DRAWINGS FOR MORE INFORMATION.
2. SHEET PILING, SHOTCRETE, & GEOTECHNICAL BY OTHERS
3. DESIGN ASSUMES NO HYDROSTATIC PRESSURE UNDER SLAB-ON-GRADE

1 WALL CONSTRUCTION JOINT - BELOW SLAB-ON-GRADE

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PROJECT 04771 CONCORD PACIFIC - AREA 6A VANCOUVER, BC

| NO. | ISSUE/REVISION | DATE | BY |
|---|---|---|---|
| 1 | CONSTRUCTION | 02/10/06 | SKC |

SCALE 1:400
DESIGNED SKC
DRAWN SO
REVIEWED JS

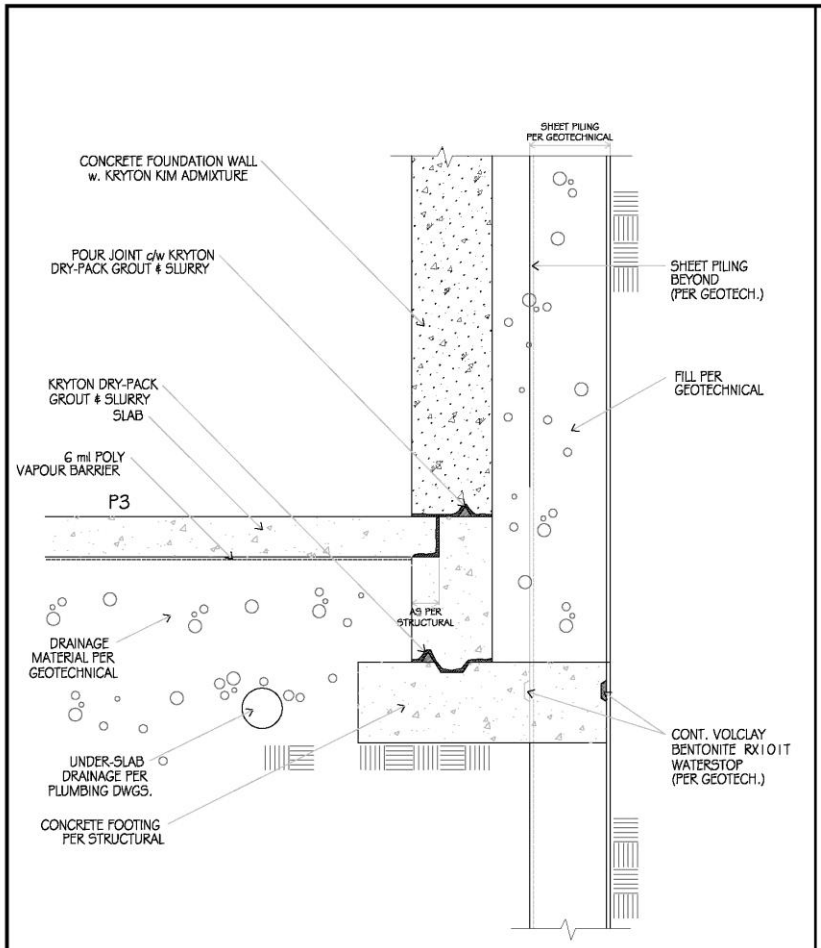
DWG TITLE
CONSTRUCTION JOINT

REVISION

DWG NO
KIM-1

# Design



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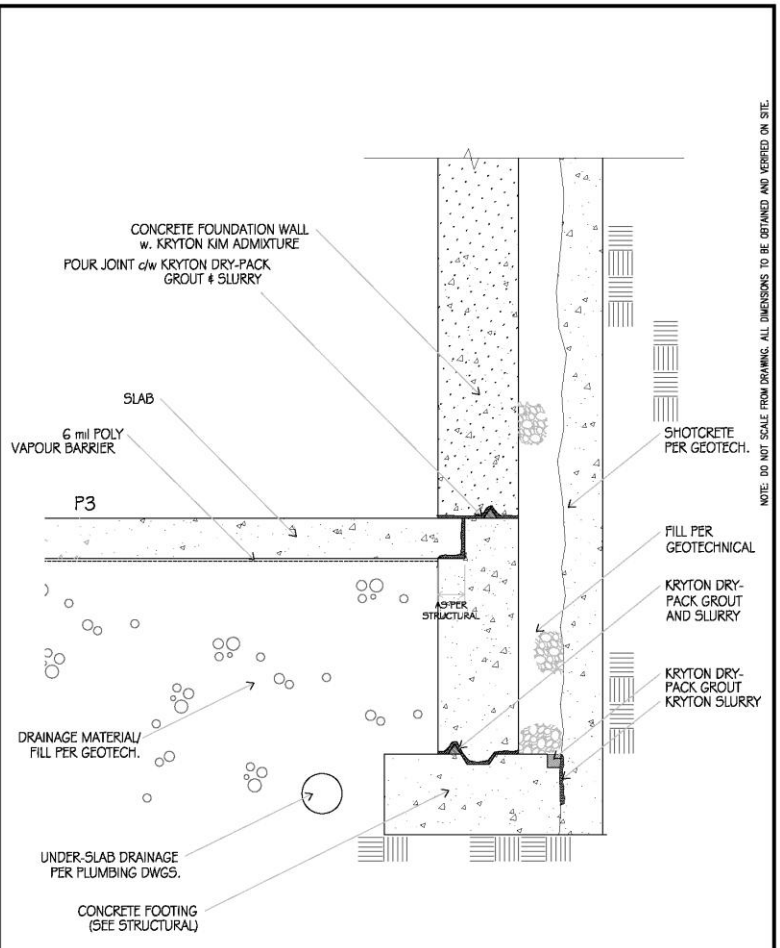
3. DESIGN ASSUMES NO HYDROSTATIC PRESSURE UNDER SLAB-ON-GRADE

1 COLD JOINT AT SLAB-ON-GRADE

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2 COLD JOINT AT SLAB-ON-GRADE

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| 1 | CONSTRUCTION | 02/10/06 | SKC |

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DWG TITLE
COLD JOINT AT SLAB-ON-GRADE

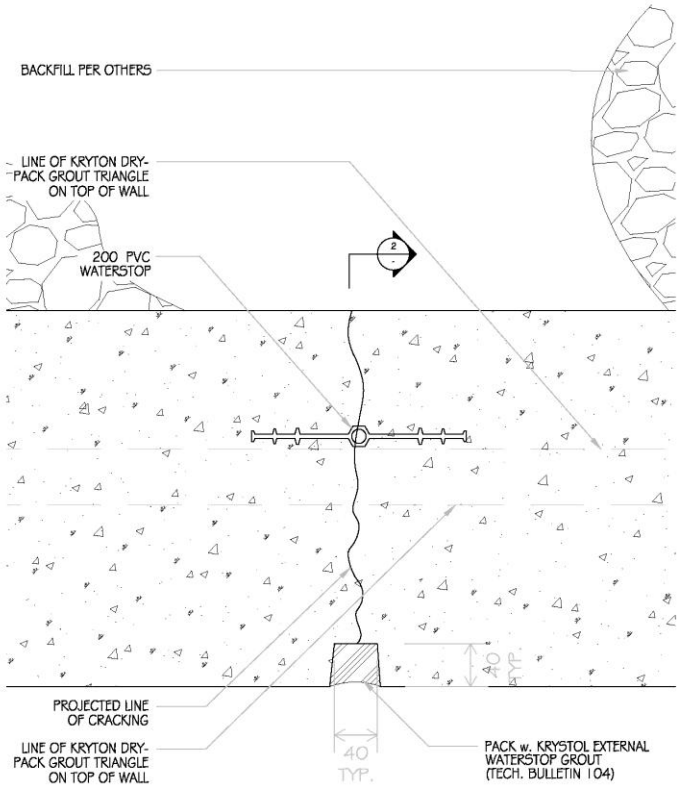
REVISION

DWG NO
KIM-2

# Design

# Design






PLAN

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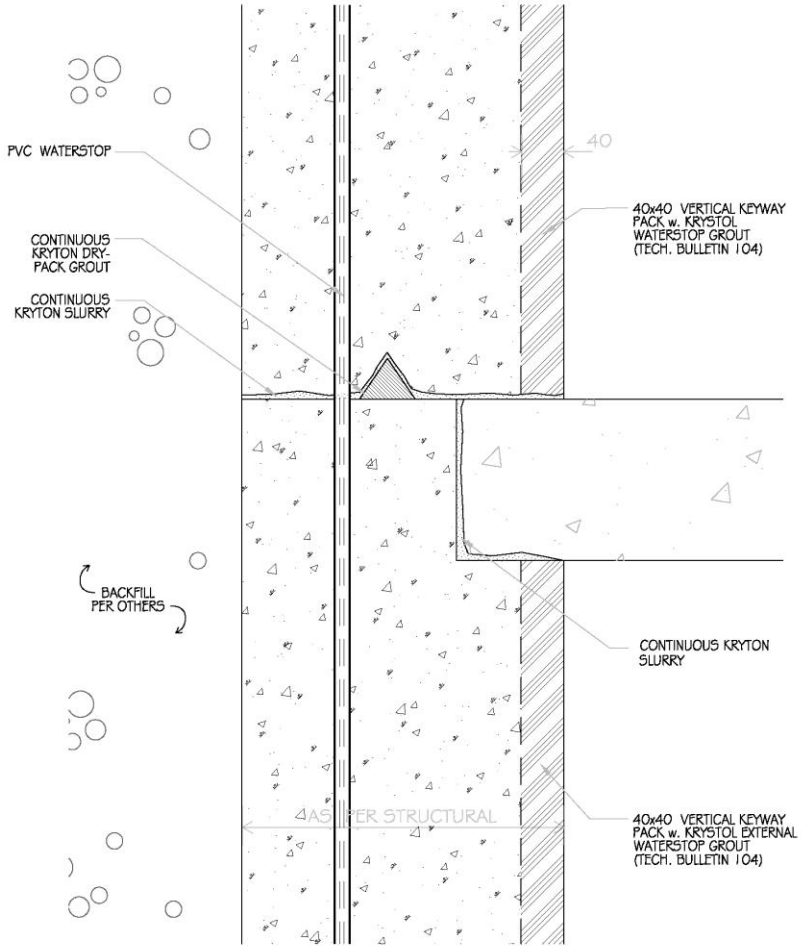
1 WALL CONTROL JOINT (BELOW GRADE)




2 WALL TO SLAB CONNECTION (BELOW GRADE)

NOTE: DO NOT SCALE FROM DRAWING. ALL DIMENSIONS TO BE OBTAINED AND VERIFIED ON SITE.

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| A | CONSTRUCTION | 02/17/06 | SKC |
| 1 | CONSTRUCTION | 02/10/06 | SKC |

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DESIGNED SKC
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REVIEWED JS

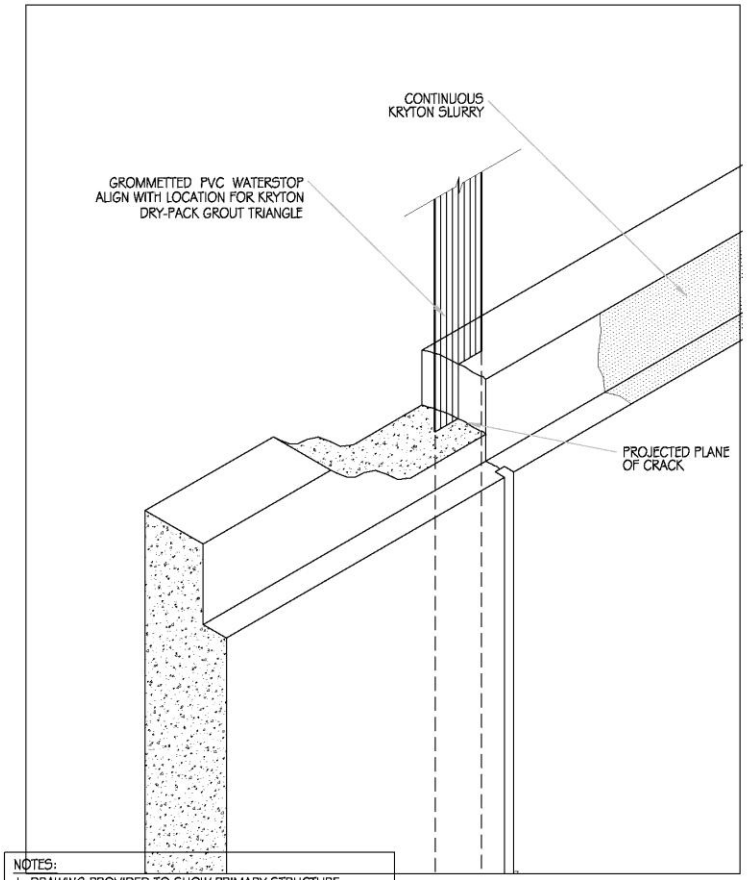
DWG TITLE
TYPICAL DETAILS

REVISION A
DWG NO
KIM-3

# Design

# Design



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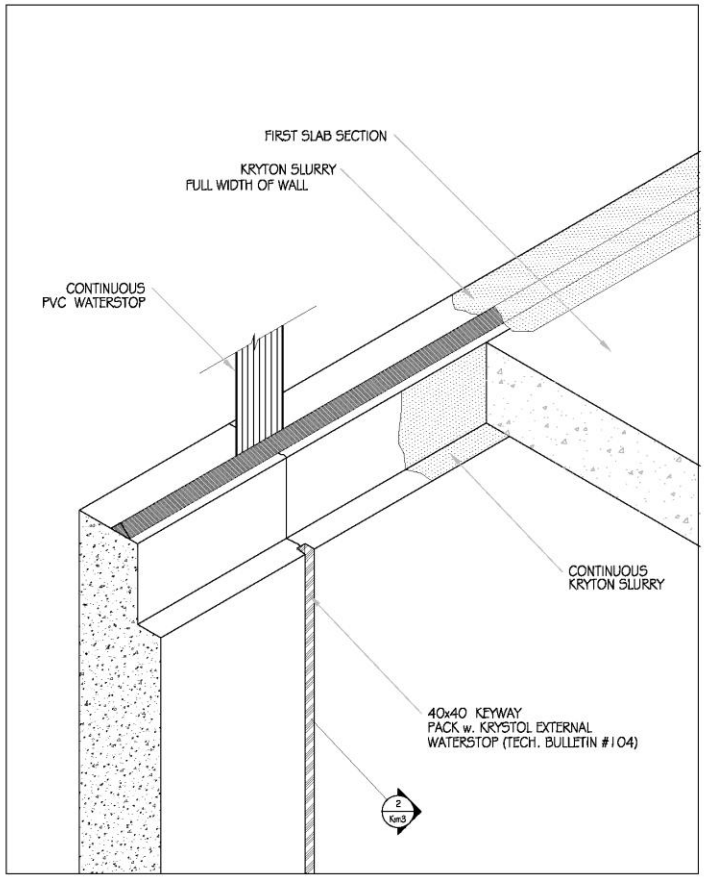
1 KEYWAY AND SLURRY AT WALL CONTROL JOINT




2 GROUT AND SLURRY AT SLAB

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| A | CONSTRUCTION | 02/17/06 | SKC |

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DWG TITLE WALL CONTROL JOINT AND FIRST SLAB CONFIGURATION

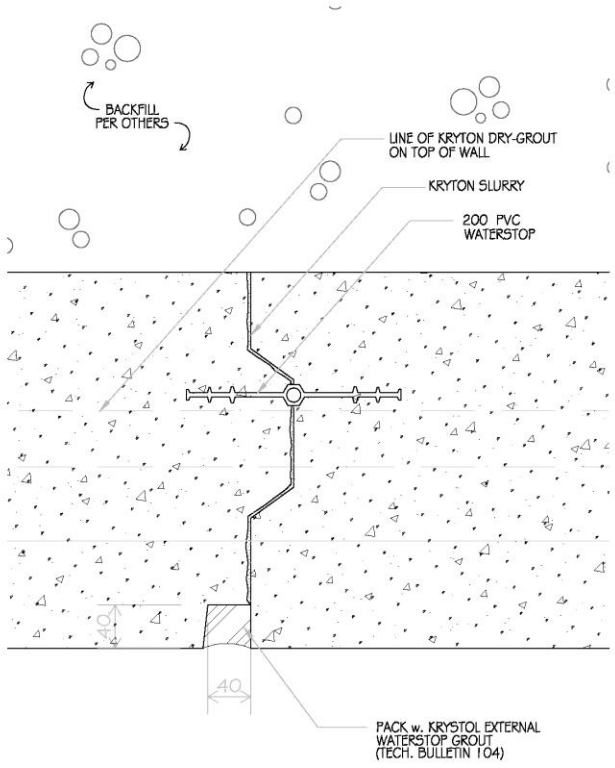
REVISION A

DWG NO **KIM-4**

# Design

# Design






PLAN

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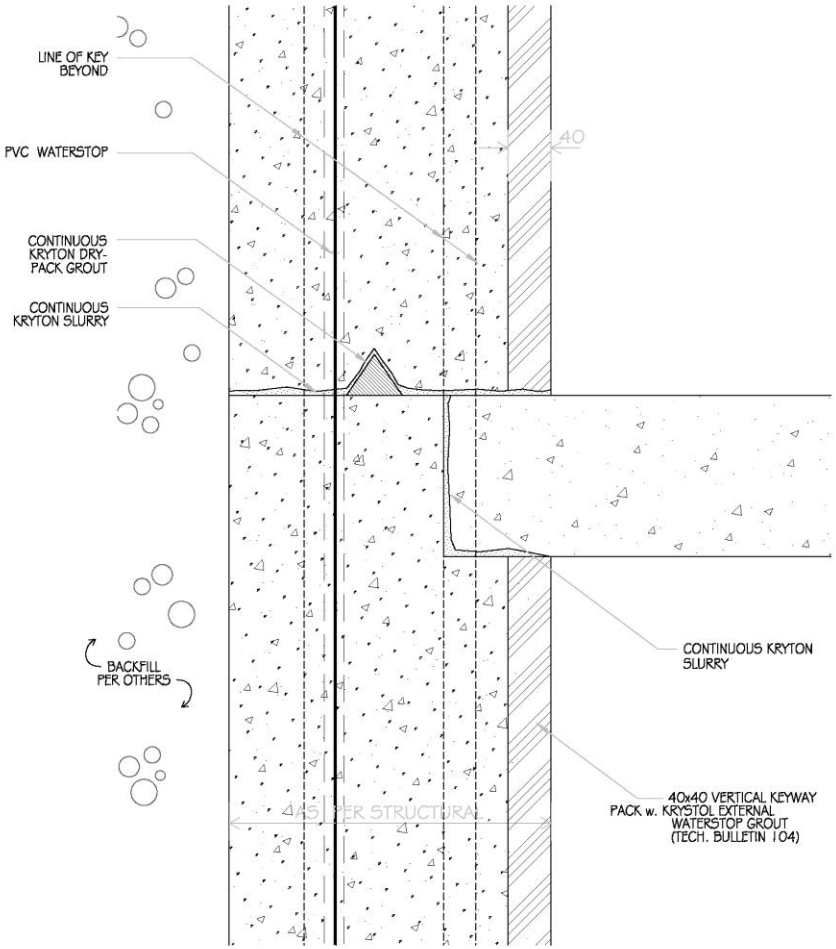
1 WALL CONSTRUCTION JOINT - TYP.




2 SECTION THROUGH WALL TO SLAB CONNECTION

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| REVIEWED | JS |

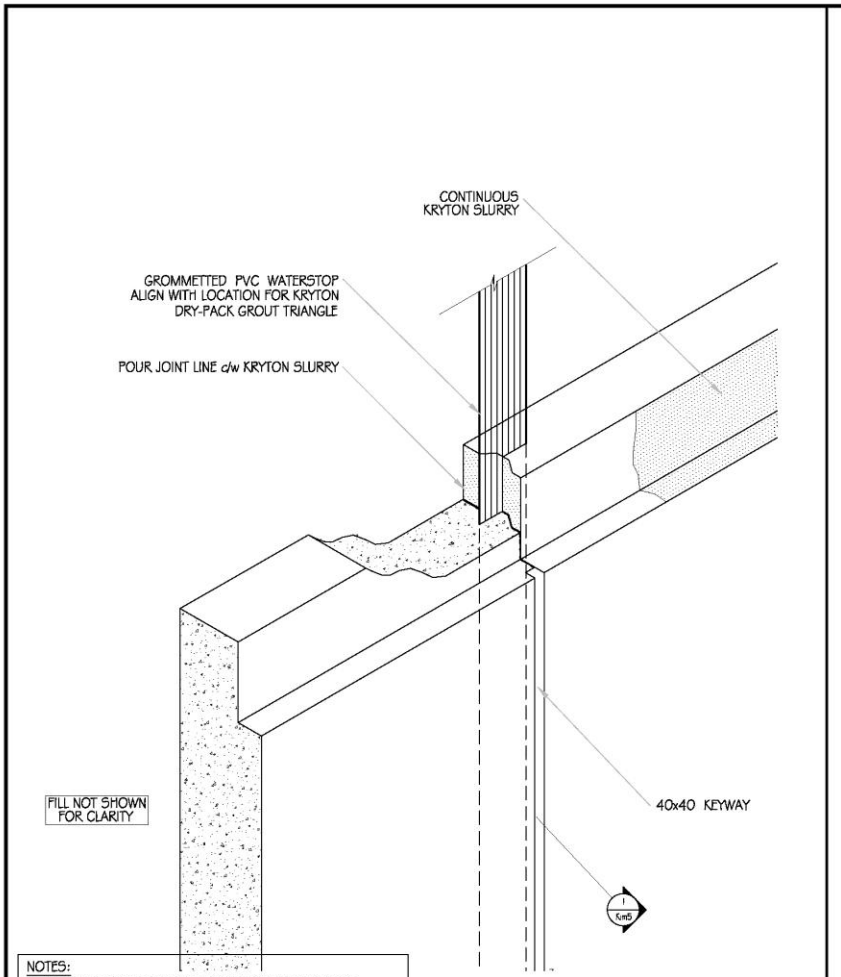
DWG TITLE: TYPICAL DETAILS

REVISION

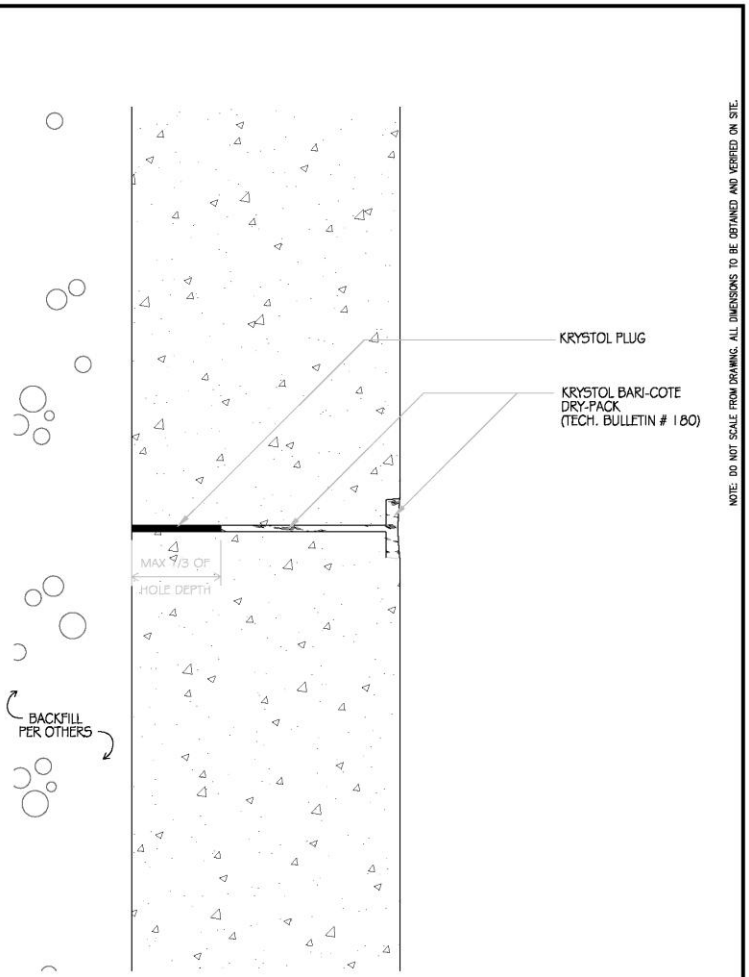
DWG NO: KIM-5

# Design






1 KEYWAY AND SLURRY AT CONSTRUCTION JOINT




2 TIE-HOLE PLUG AND DRY-PACK

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| 1 | CONSTRUCTION | 02/10/06 | SKC |

SCALE AS NOTED
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DRAWN SO
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DWG TITLE TYPICAL DETAILS

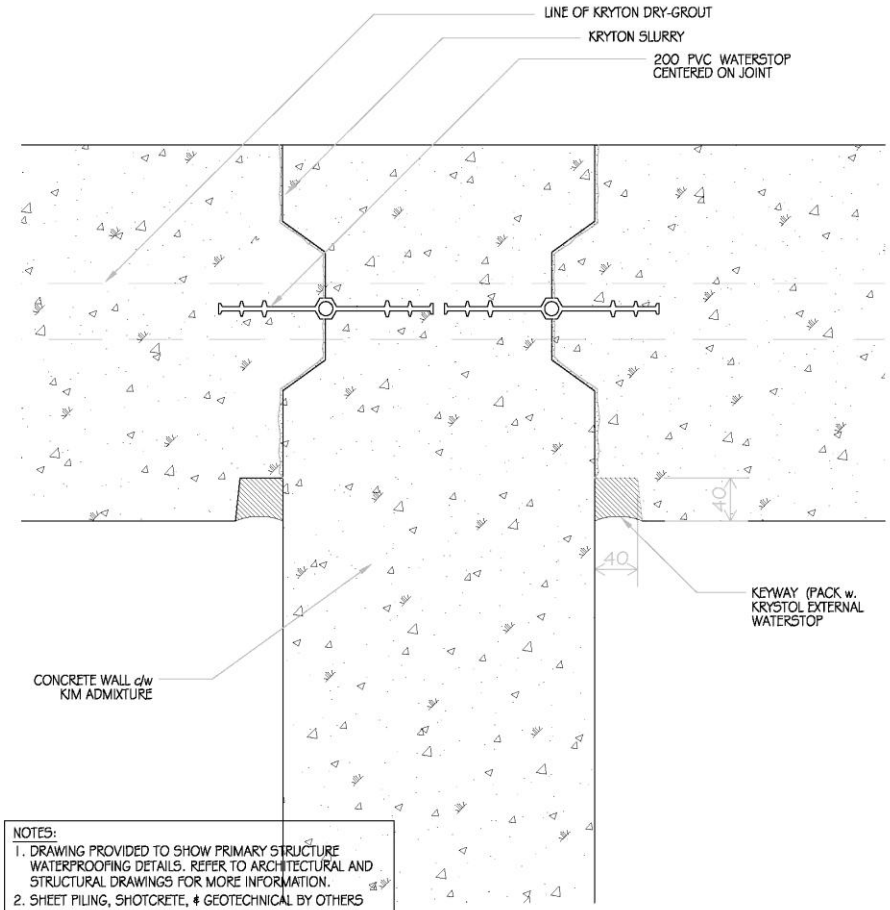
REVISION

DWG NO **KIM-6**

# Design

# Design



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1 WALL CONNECTION AT P4 (NORTH EL., GRID A-B)

2

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| REVIEWED | JS |

DWG TITLE
CONSTRUCTION JOINT LEVEL xx

REVISION

DWG NO
KIM-7

# Design

# CONSTRUCTION

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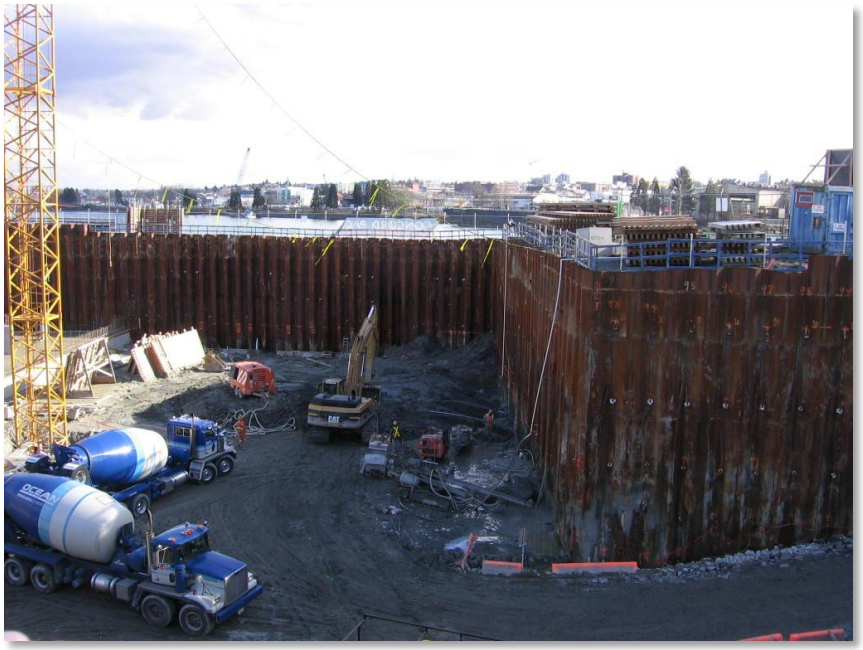
- ✓ Sheet piles used to retain soil and moisture from False Creek
- ✓ Lengthy process sequenced so forming could be ongoing in one hole while excavation was in progress in other areas



- ✓ Large boulder was found during excavation at Case Study 2 location
- ✓ Impractical to remove boulder
- ✓ Adjustment made to design in consultation with structural engineer to accommodate boulder being left in place

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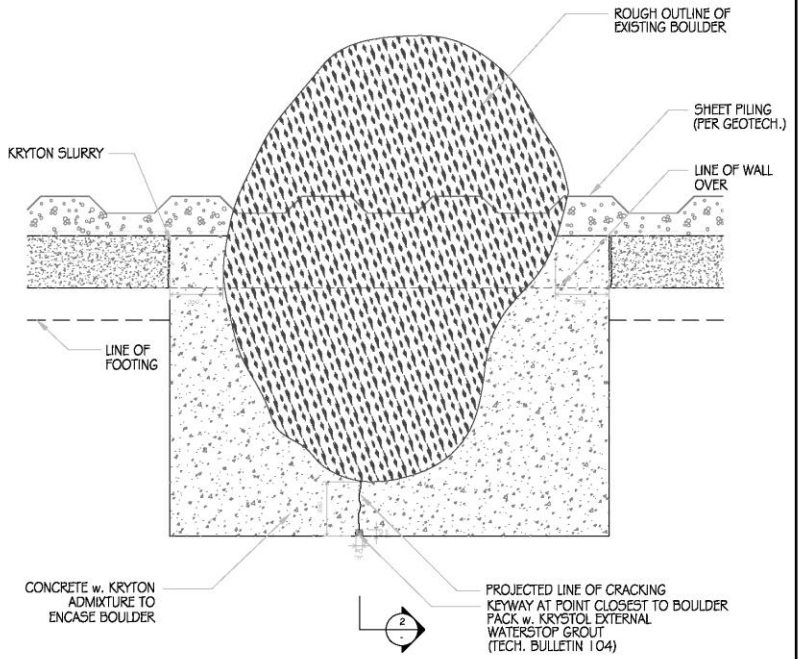
# Design






PLAN

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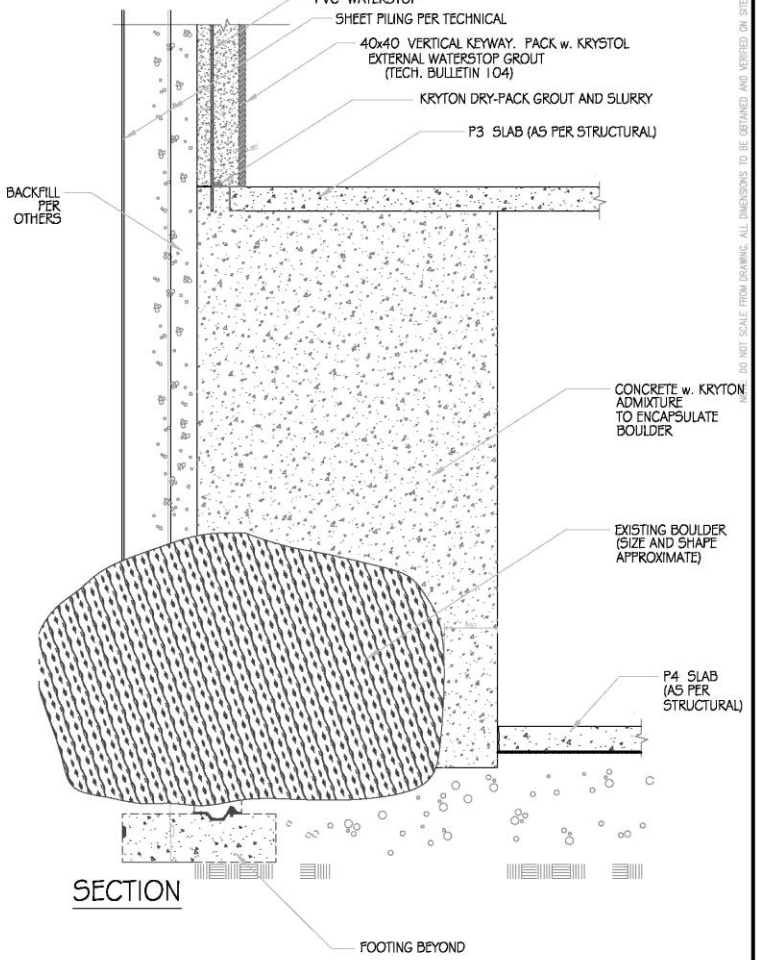
1 BOUNDER ENCAPSULATION




SECTION

2 WALL TO SLAB CONNECTION (AT BOULDER)



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| NO. | ISSUE/REVISION | DATE | BY |
|---|---|---|---|
| 1 | CONSTRUCTION | 02/22/06 | SKC |
| A | CONSTRUCTION | 02/27/06 | SKC |
| B | CONSTRUCTION | 03/09/06 | SKC |

| | |
|---|---|
| SCALE | 1:150 |
| DESIGNED | SKC |
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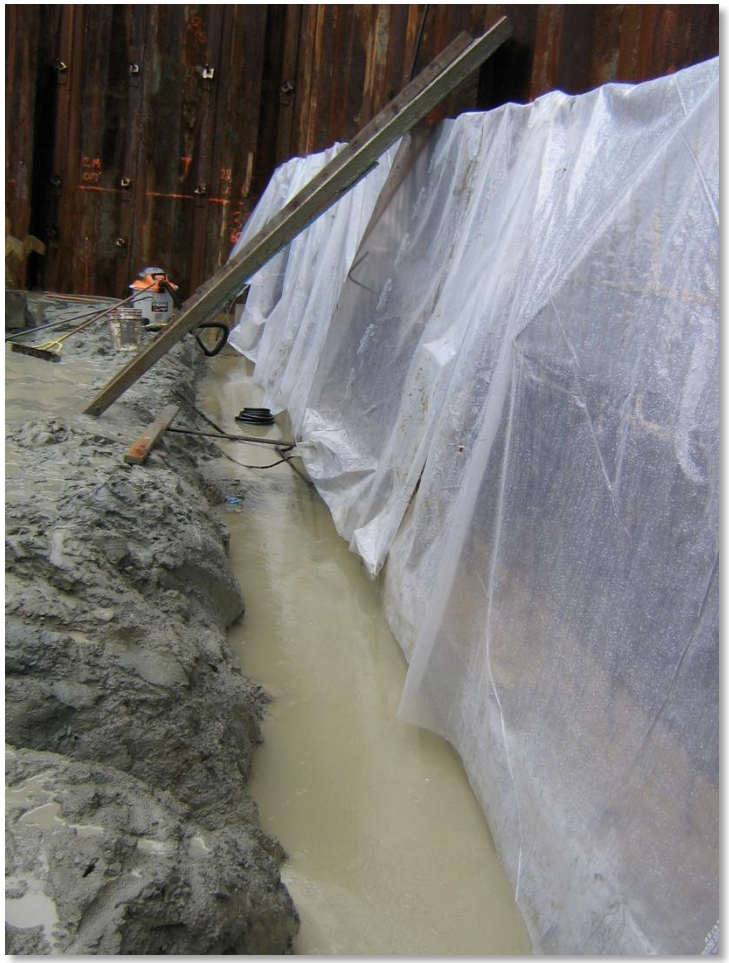
| REVIEWED | JS |

DWG TITLE
BOULDER TREATMENT

REVISION B

DWG NO
KIM-8

- ✓ Constant de-watering during excavation and forming
- ✓ Mud had to be kept clean from concrete
- ✓ Grout and slurry had to be applied damp and kept dry to cure
- ✓ Tarping required for contractor to apply product in the rain



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- ✓ Below slab on grade de-watering system
- ✓ Footing poured against piles

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- ✓ Footing wall covered in water
- ✓ During construction, constant de-watering required to install grout and slurry
- ✓ Grout and slurry washed off if exposed to water before curing

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## Perimeter drainage inside pony wall at footing

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# Slab-on-grade at lowest level

- ✓ PVC water stops fastened to reinforcing steel
- ✓ Difficulty keeping PVC water stop in place during pours
- ✓ Water stops dislodged during pour become ineffective

- ✓ Water stops used in addition to keyways for grout to be applied later
- ✓ Grout and slurry at vertical provided second line of defence against water penetration at vertical joints

**Gravel and polyethylene sheet installed below slab on grade**

**Slurry applied to pony wall transition prior to pouring slab on grade**

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# Typical suspended slab forming

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- ✓ Key in foundation wall formed to receive slab
- ✓ Key coated with slurry only
- ✓ Kryton admixture in foundation wall covers slab edge

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- ✓ Tarping was often used during application of grout and slurry
- ✓ Once fully set, grout and slurry could be exposed to weather

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# Reinforcing steel at suspended slab hooked into steel at wall

- ✓ Large runs of slurry could be applied prior to pouring slab

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- ✓ Suspended slab poured onto shelf of foundation wall
- ✓ Minimizes exposed cold joints to one rather than two in conventional forming practices

- ✓ Grout triangle placed onto damp foundation wall
- ✓ Once cured (several hours) slurry can be applied

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- ✓ Critical to have no debris in formwork
- ✓ Prior to closing in formwork, grout and slurry were reviewed and bottom of form cleaned

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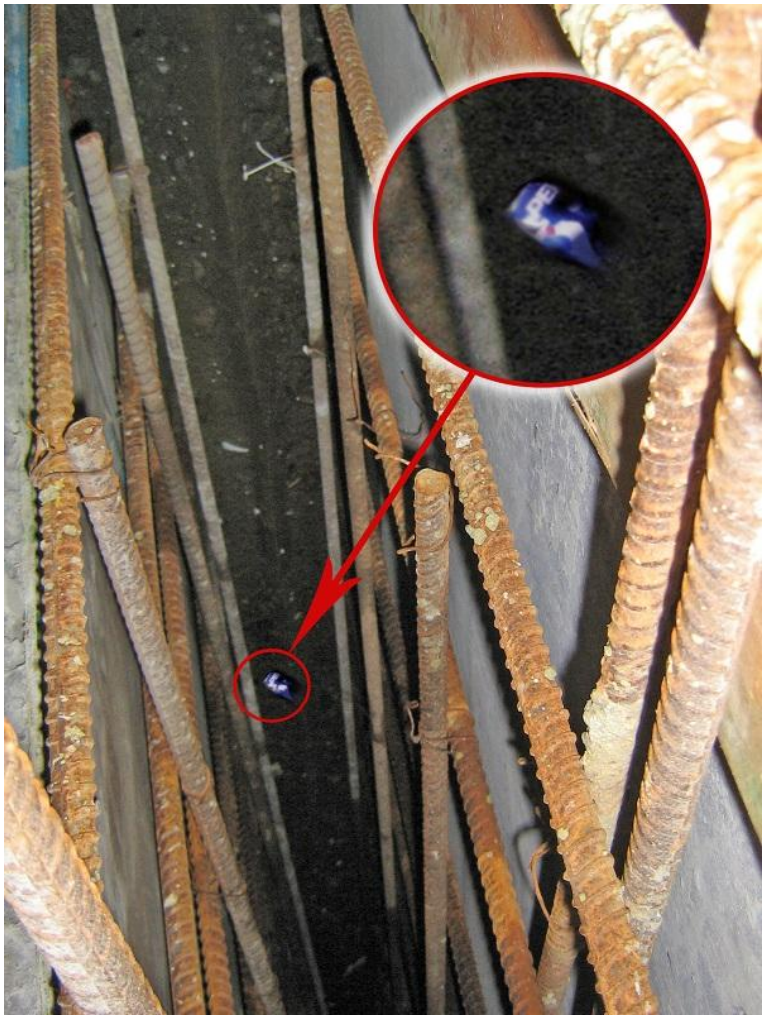
- ✓ After formwork closed in and prior to concrete placement, completed formwork reviewed.
- ✓ Zero-tolerance for debris!
  - Formwork opened up and debris cleaned.



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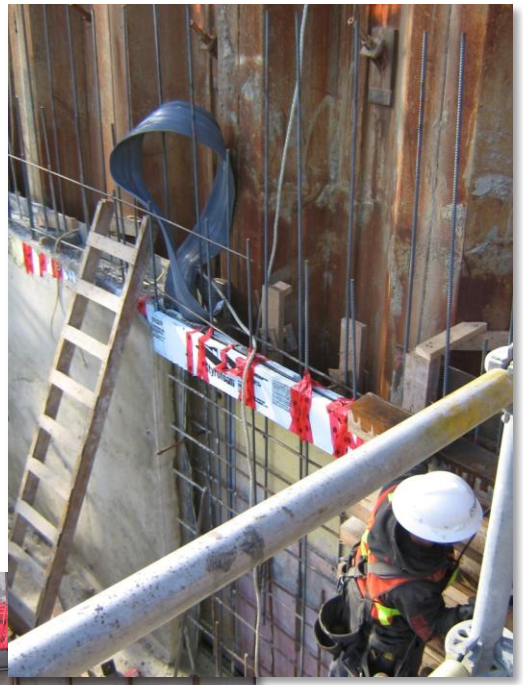
- ✓ PVC water stop and slurry at vertical joints
- ✓ PVC water stop was continuous from floor to floor
- ✓ Keyway left for grout at a later date



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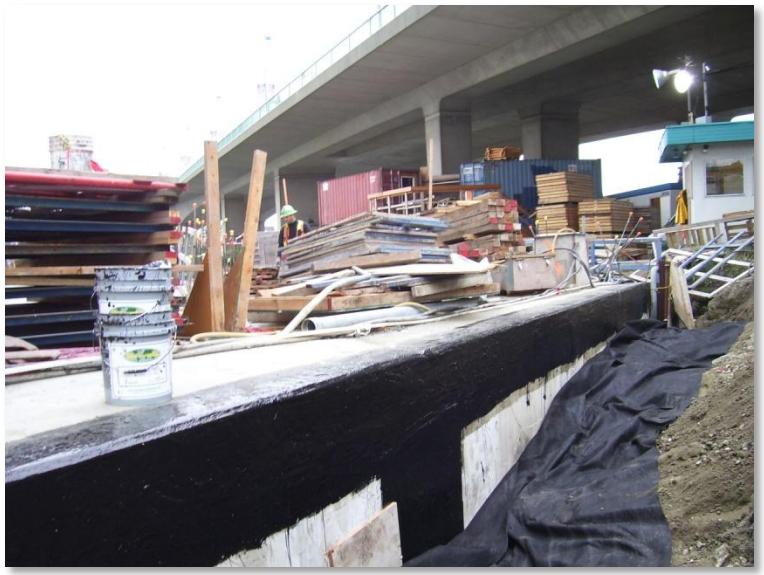
- ✓ Cutting of piles required to perform membrane tie in over slab edge
- ✓ Backfilled once membrane installation complete



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- ✓ Many cracks and leaks remained after construction of parkade was completed.
- ✓ Developer wanted to wait as long as possible to repair cracks to minimize the risk of new cracks occurring and allow self-sealing capabilities to work as much as possible

# POST CONSTRUCTION

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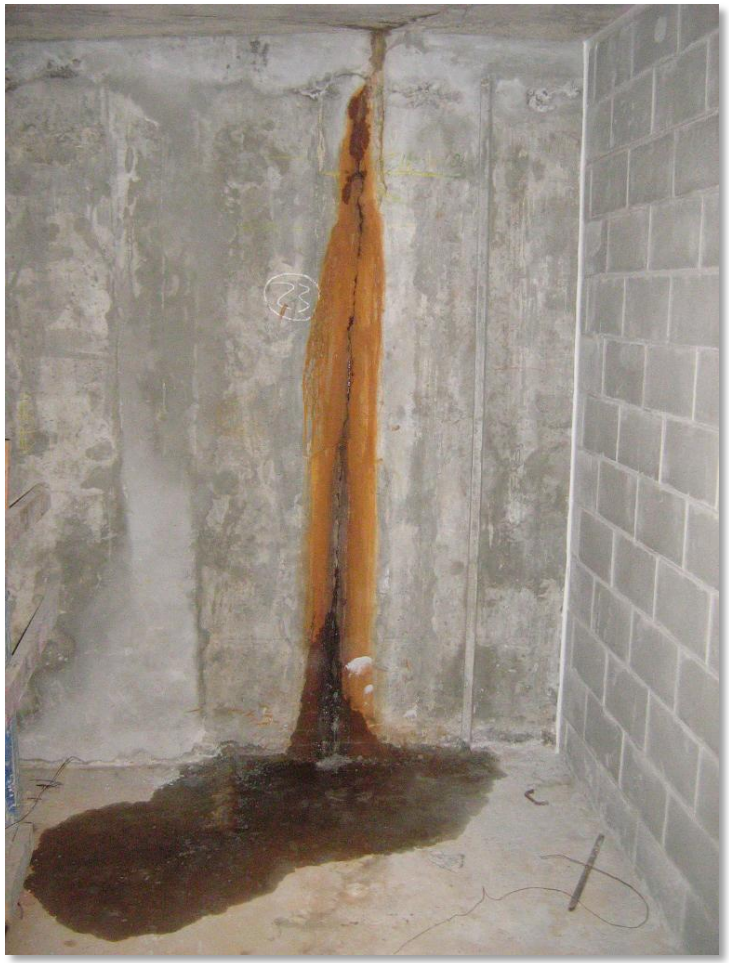
# Leak Review Prior to Construction Completion

- ✓ 2006 parking garages complete
- ✓ Initial survey found more than 40 leaks
- ✓ Some initial crack repair was conducted
- ✓ Leaks continued as construction of structure progressed and concrete cured



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# Leak Review Prior to Construction Completion

- ✓ Cracks and leaks were generally located at control joints

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# Leak Review Prior to Construction Completion

- ✓ Cracks also occurred:
  - Adjacent to control joints
  - At changes in wall thickness
  - Base of wall

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# Leak Review Prior to Construction Completion

- ✓ Some cracks initially repaired continued to leak
- ✓ In some instances, the original repairs were <u>not</u> carried out according to manufacturer's recommendations

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# 2010 Warranty Review


- ✓ Signs of crystal growth were noted in more than 20 areas during 2010 warranty review
- ✓ No active leaks were observed
- ✓ Red flags were raised by Strata due to their lack of understanding or belief in the system
- ✓ Third party retained by Strata to review leaks

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# 2010 Warranty Review

## Krystol residue after 2010 warranty review


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# Lessons Learned

- ✓ System success depends on materials and methods of install (no different than anything else)
- ✓ Must be considered as a system and not a product
- ✓ Overall solution involving architect, envelope, structural engineer, supplier, and contractor, where all parties need to coordinate and understand the system.

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# Lessons Learned

- ✓ Implementation requires buy-in from trade (formwork contractor) performing the work
- ✓ Be aware that less skilled labourers may be doing preparation work
- ✓ Formwork foreman was “point-man” Quality consistency was variable (typical to all trades) readily identified and easily corrected
- ✓ Thorough quality control and assurance systems are crucial to project success

# Lessons Learned

- ✓ End user may have difficulty understanding the system or accepting how it works – proper information in maintenance manual
- ✓ Third party (other consultants) may not understand system
- ✓ Repairs generally performing well
- ✓ System developing good performance history in this market

# Lessons Learned

- ✓ All systems are weather dependent (damp was OK but ponding or running water detrimental
- ✓ System only requires protection / water extraction during initial application
- ✓ Durable; difficult to damage and easy to repair once set up
- ✓ Needs coordination with other trades, particularly reinforcing steel
- ✓ Other trades may not respect the system (reinforcing steel trade often destroyed grout)

# JRS' Use of Integral Waterproofing

- ✓ Critical factors in the successful use of integral waterproofing for the False Creek project included:
  - Wall design: spacing of construction & control joints *(Reducing spacing as much as possible)*
  - Mix design and types coming out of batch plant
  - Actual admixture put into concrete *(Batch accountability and quality control)*
  - Preparation of joints, including triangular grout
  - Careful field quality control and good basic concrete techniques
  - Rigorous field quality control of detailing, formwork and pre-placement

# Thank You

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