Quality Control of Silica Fume Bridge Decks

Salt Lake City, Utah
March 27, 2018

SKANSKA Kiewit ECCO
JOINT VENTURE

Quality Control of Silica Fume Concrete Bridge Decks

Unless batched, handled, and placed with tight controls and optimal conditions, silica fume decks can suffer wide spread cracking thru several mechanisms. Determination of the causes, assessment of the damage, considerations for repairs, and corrective actions moving forward enlist the experience and innovation of the whole project team.

KOSCIUSZKO BRIDGE

Brooklyn – Queens Expressway, Brooklyn, NY

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KOSCIUSZKO BRIDGE – Phase I

Brooklyn- Queens Expressway, NYC

- Replacement of a 6 lane bridge, built in 1937
- First of a pair to be built by NYS DOT
- 180,000 vehicles per day
- Design build - $550 million
- SKE Joint Venture (Skanska – Kiewit – ECCOIII)
- Design Engineer - HNTB
- Independent REI services Liro Engineering
- Independent Testing by Tectonic Engineering

Brooklyn Connector	*Brooklyn App. Spans*	*Main Span*	*Queens App. Spans*	*Queens Connector*
2000’	**1000’**	**1000’**	**1000’**	**700’**

- 1000’ ***cable stay main span*** with precast deck panels
- 1000’ foot ***approach decks*** either side on either side with HP decks set on 120’ spans of AASHTO Bulb T Girders.
- 2000’ and 700’ Connector Roadways on T-Walls and fill with spans over local streets

KOSCIUSZKO BRIDGE – (Phase I and II shown)

Brooklyn – Queens Expressway, Brooklyn, NY

Design Life Criteria

Bridge Decks

a. 100 year life
b. HP concrete and SS bar

Structural slabs on grade

a. 75 year life
b. HP and Epoxy bar

Compressive Strength

a. F'c = either 4000 or 5000 psi
b. 5000 psi used

Qualification of Mix Designs

Stadium Analysis STADIUM uses time-step finite element analysis to simulate the progress of harmful ions (including chloride, sulphate, and hydroxide) through concrete, by considering the chemical and physical properties of the concrete being analyzed.

Qualification Testing included:

- Compressive Strength
- RCP (Rapid Chloride Penetration)
- Freeze-thaw for 28 and 56 day cured samples
- 50 cycle scaling for 28 and 56 day cured samples

Total = 106 days to qualify a mix

Design Mixes for Superstructures

Mix	Total Cementitious	Slag	Fume	w/c	Sand Vol.	Stone Vol.
HP	650	40%	6%	0.4	28%	38%
Mass	625	70%	0	0.37	31%	37%
Pylon	676	50%	0	0.36	36%	35%

Three locations to use HP (Silica Fume) Concrete

1. Connector bridge decks over local streets.
2. Connector slabs on grade *"Moment Slabs"* by the T-Walls
3. Approach Spans adjacent to the Main Span

Total Yardage

- 14,000 CY
- 97 placements

Characteristics of HP (Silica fume) mixes

- Strong and impermeable
- Quick strength gains with resultant heat
- Autogenous shrinkage with low w/c ratio
- Plastic shrinkage due to lack of bleed water
- Prone to cracking

Considerations for Using HP mixes

- Not just about material testing
- Shapes, aspect ratios
- Construction joints
- Restraint
- Placement and curing conditions.

Concrete Testing

- Plant Inspection by NYSDOT
- Field Testing by Tectonic Engr'g
- Supervision by LiRo Engr'g

Test Results –

Compressive Strength

- 7 day avg. 5802 psi SD=1005 psi
- 28 day avg. 8619 psi SD=1224 psi
- 56 day avg. 9779 psi SD= 1283 psi

Rapid Chloride Penetration

- 280 Coulombs avg. SD=97

Criteria for Structural Slabs

- 7 or 14 day cure at 45 degrees F (min)
- Repair all cracks over 0.007” (see ACI 224.1)
- Structural elements - two coats Silane – typical (good for 1/16” cracks per mfr.)

Table 4.1—Guide to reasonable* crack widths, reinforced concrete under service loads

Exposure condition	Crack width	
	in.	mm
Dry air or protective membrane	0.016	0.41
Humidity, moist air, soil	0.012	0.30
Deicing chemicals	0.007	0.18
Seawater and seawater spray, wetting and drying	0.006	0.15
Water-retaining structures†	0.004	0.10

*It should be expected that a portion of the cracks in the structure will exceed these values. With time, a significant portion can exceed these values. These are general guidelines for design to be used in conjunction with sound engineering judgement.

†Exclusing nonpressure pipes.

VIEW FROM BROOKLYN

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Main Span

- 1000’
- Precast Deck Panels with infills
- Polymer overlay

Approach Spans – Brooklyn (Queens similar)

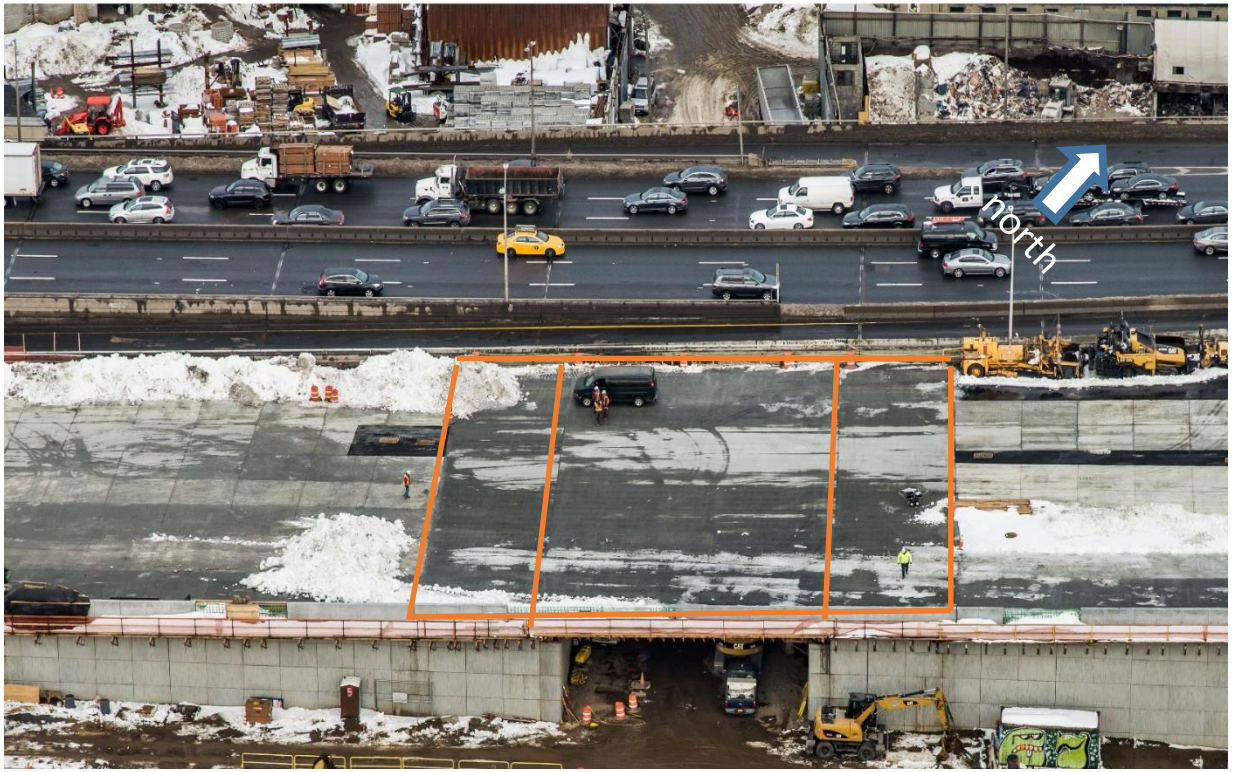
- 8 spans at 120 feet each – EJ at either end.
- AASHTO Bulb Tees
- 9 inch decks with SS #4‘s at 8” in both directions (HP mix)

Connector Roadway – Brooklyn (Queens similar)

- 2000’
- T wall retaining structures with Std road slabs
- “*Moment Slabs*” adj. to facias (HP mix)
- Bridges over local streets – (HP mix)

Typical Connector Bridge Deck

- 8.5 inch decks - #4's SS at 8" (T & B)both ways – 2" cover
- Steel Stringers with shear studs
- Backwall dowels to Deck and App. Slabs



Connector - Varick Bridge Deck and App. Slabs

- 8.5 inch deck with #4's SS at 8" OC
- Steel Stringers with shear studs
- 60' span with 28' app. Slabs – placed 100' wide

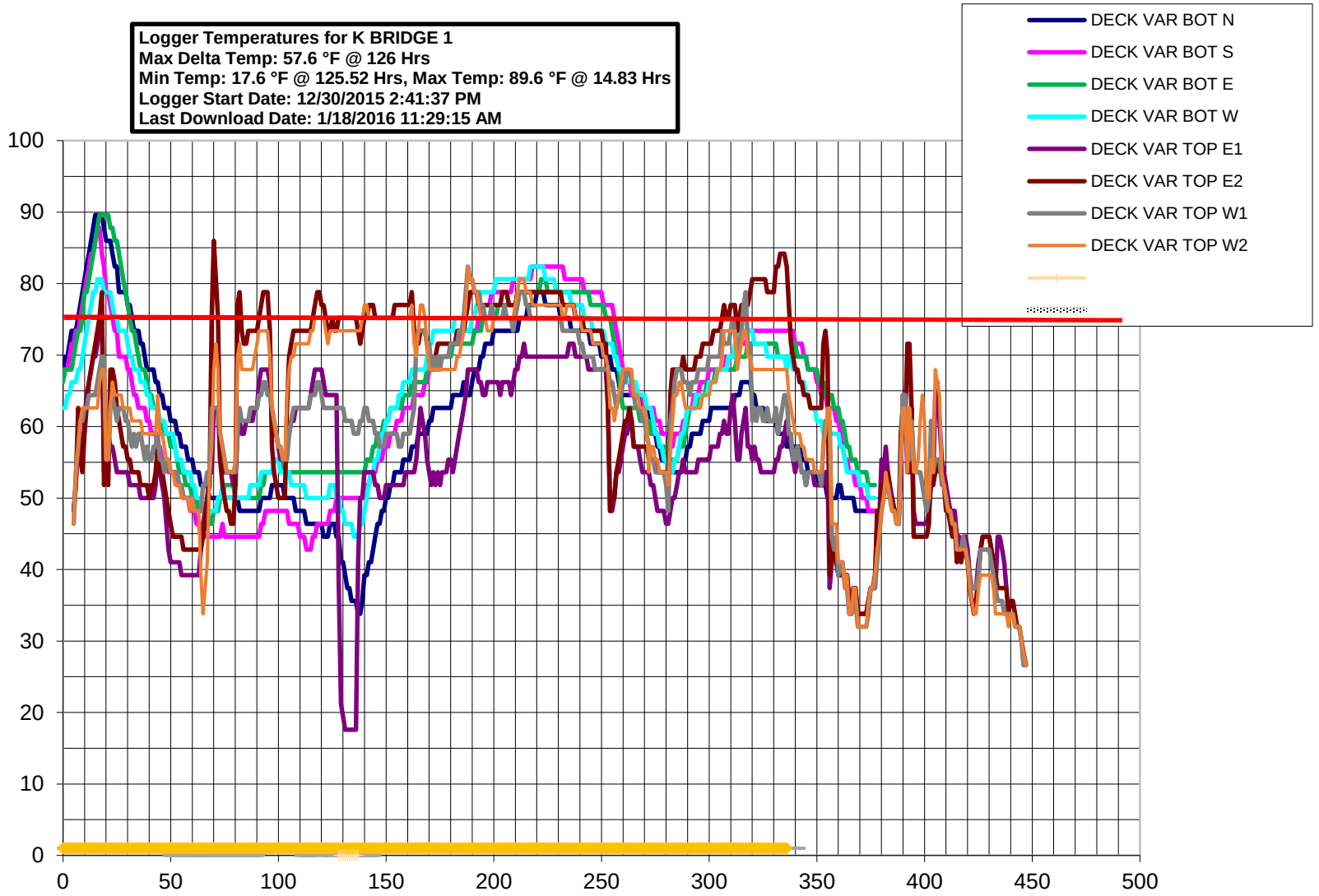
Varick Ave. Bridge Deck and App. Slabs

Approach slabs on grade – 28’ X 100’ wide’

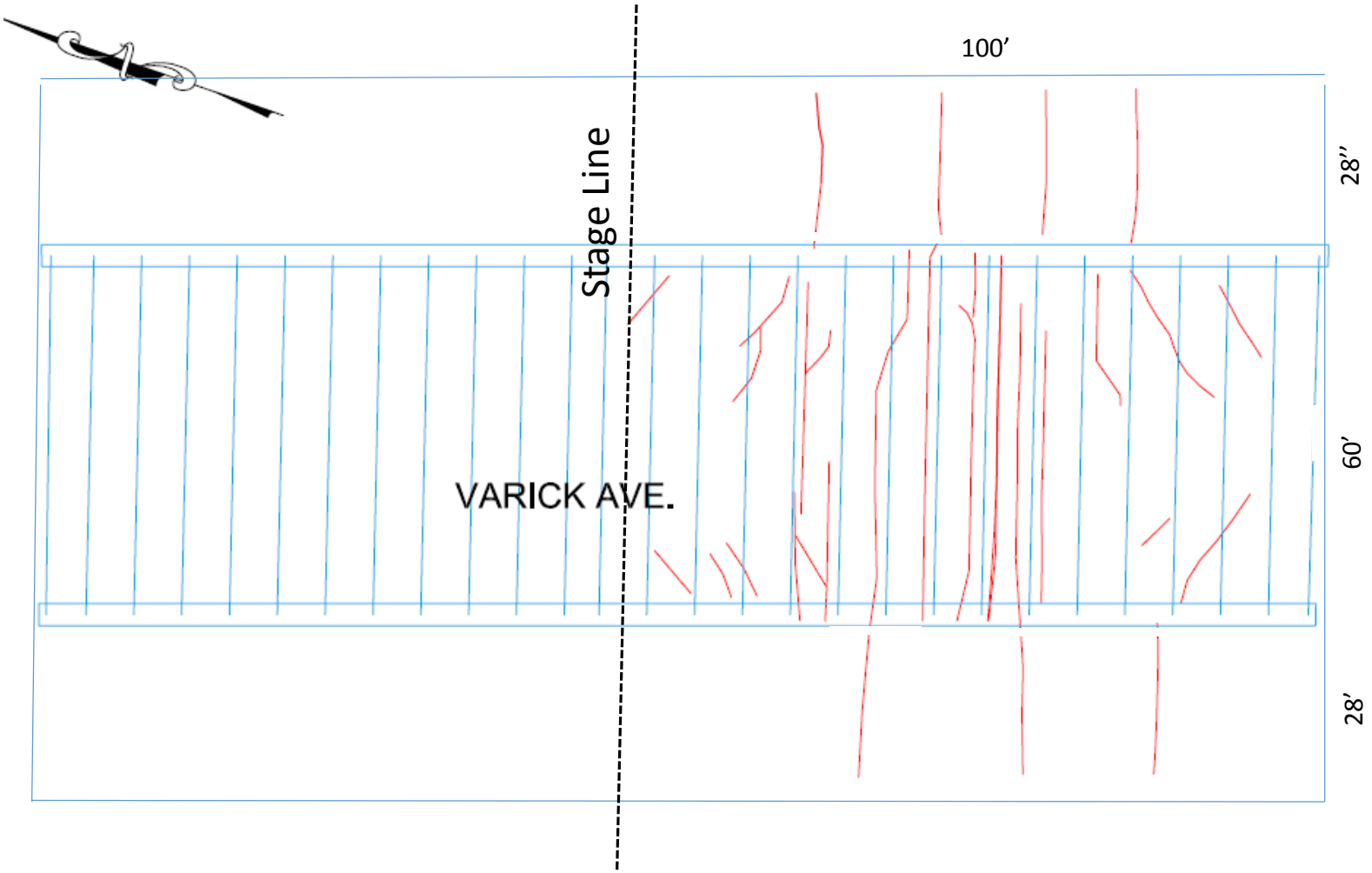
- Used vibrating screed orientated with the roadway
- Cured with wet burlap and blankets

Bridge span 60’ X 100’ wide

- Used one Bidwell to travel the 100’ transversely
- Winter conditions
  - glycol hoses top
  - burners underside -
  - avg. cure temp 75F at 18 hour mark
- Scrimped on water - mix too stiff – surface overworked
- Late in applying burlap cure – followed with blankets



Varick Temperature Data



Varick Ave – The Result

Vandervoort Ave Bridge Deck

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Vandervoort Deck Placement

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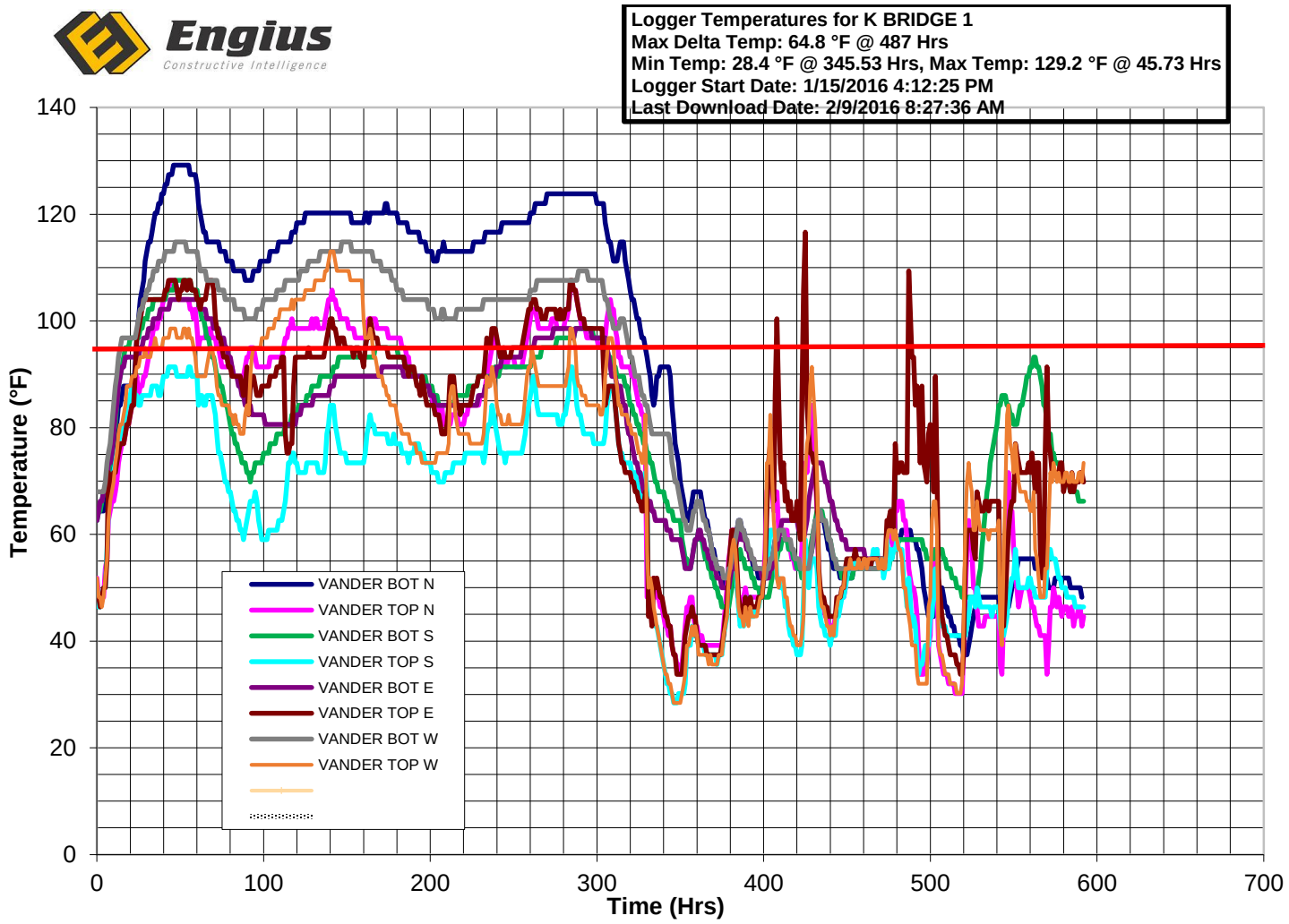
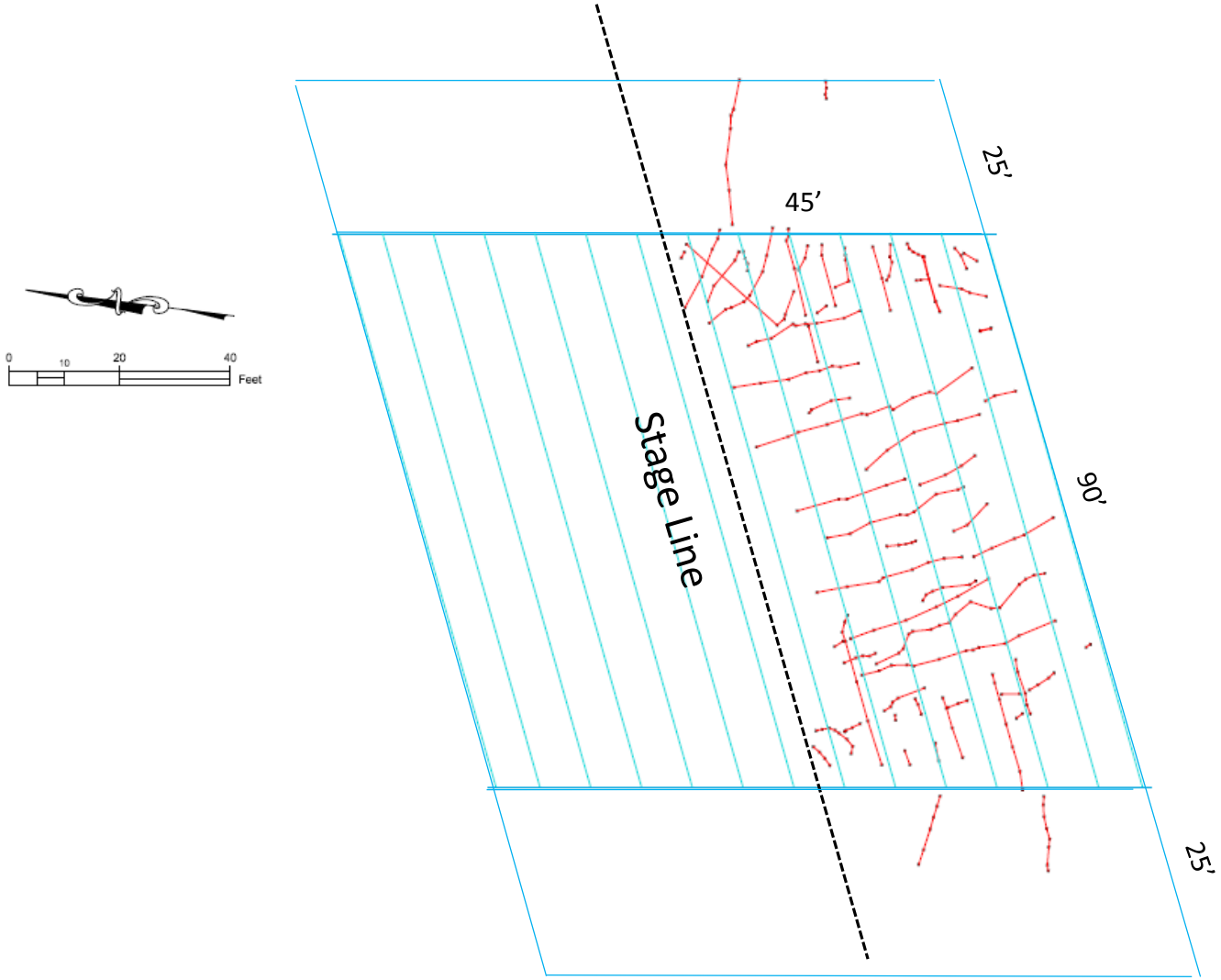
Vandervoort Ave. Bridge Deck

The span 90’ X 45’ wide

- Used one Bidwell to travel the 45’ transversely
- Slump was workable
- Late in applying wet burlap cure
- Winter conditions
  - Glycol hoses top
  - Burners under and thru stringer bays
  - Avg. cure temp 94F at 24 hour mark



Vandervoort Temperature Data



Vandervoort Ave – The Result

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Connector Bridge Deck Cracking

Contributing factors

- Restraint - steel stringers w/studs, deck dowels to abutments, no exp. Jnts -
- Does not act like a microsilica overlay
- Scrimping on water - great self desiccation, harder finishing, overworking the surface, longer time to place covers.
- Late in placing cure covers
- High curing temperatures –self desiccation and thermal shrinkage

Investigation and repair

- Removed SIP deck in spots on deck bottom to see if thru cracked
- Map out cracks to determine pattern
- Determine crack widths – greater than 0.007” to be sealed
- Seal cracks with MMA
- Finish with silane – two coats

Connector Bridge Decks – Moving forward

For all slabs

- Seal all cracks over .007”
- Call in some experts
- Have someone at the plant for batching and moistures
- Add all the water
- Fog and set curing covers quickly
- Minimize placement temperatures
- Optimize Bidwell adjustment to minimize of overworking the surface
- For wide decks - use two Bidwell carriages on one truss to boost paving speed.

Connector Bridge Deck – Crack Sealing with MMA

Connector Roadway with Moment Slabs

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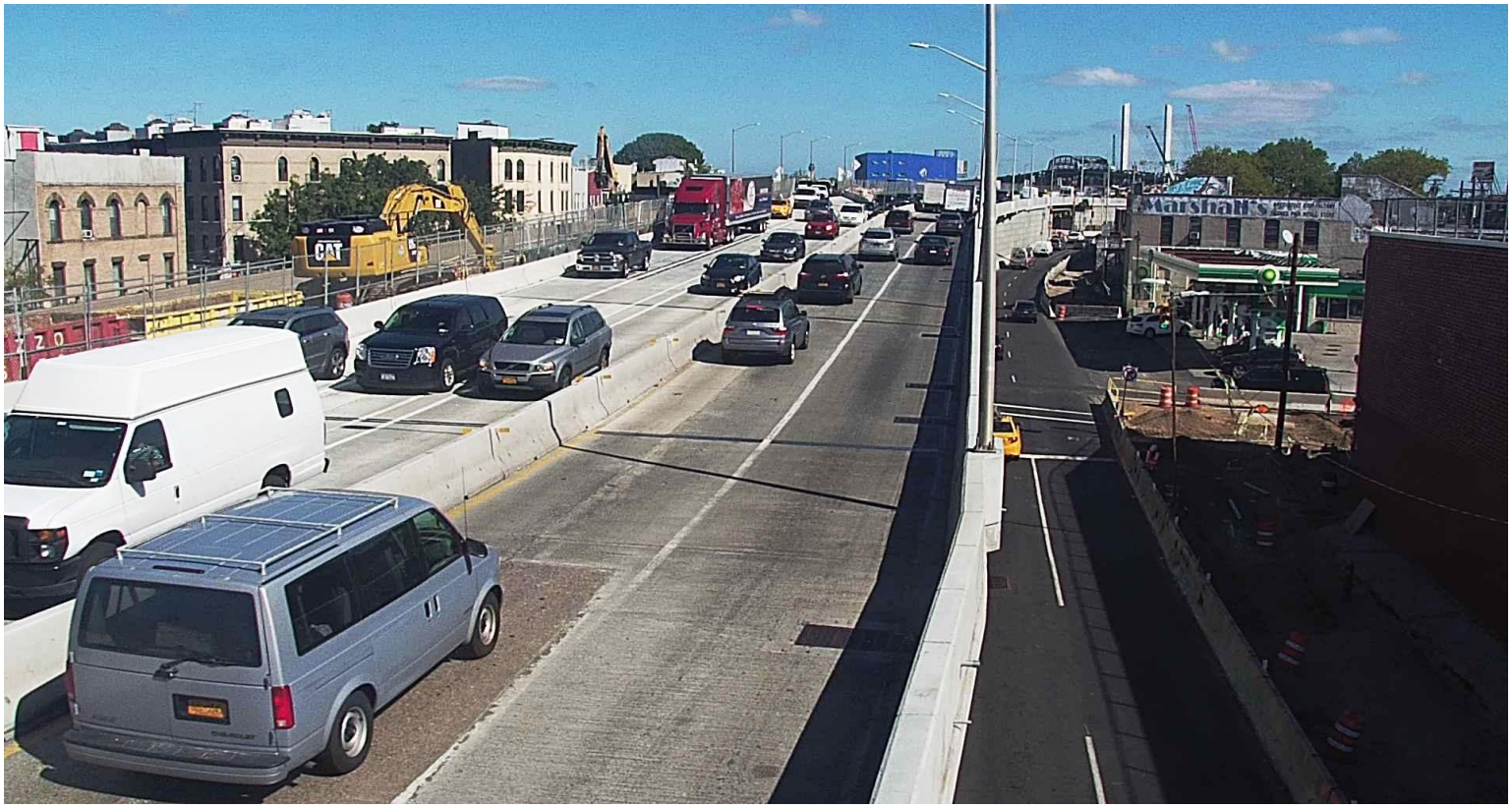
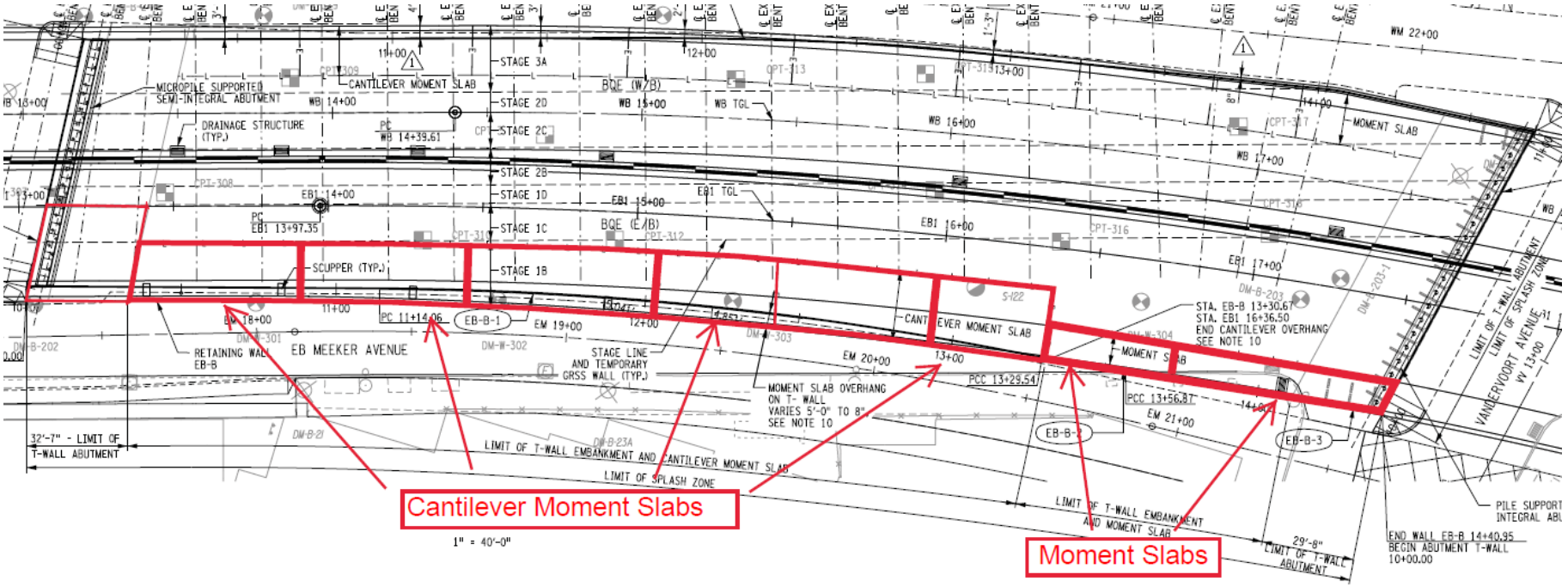
Brklyn Connector T-Walls w/ Cantilever Moment Slabs

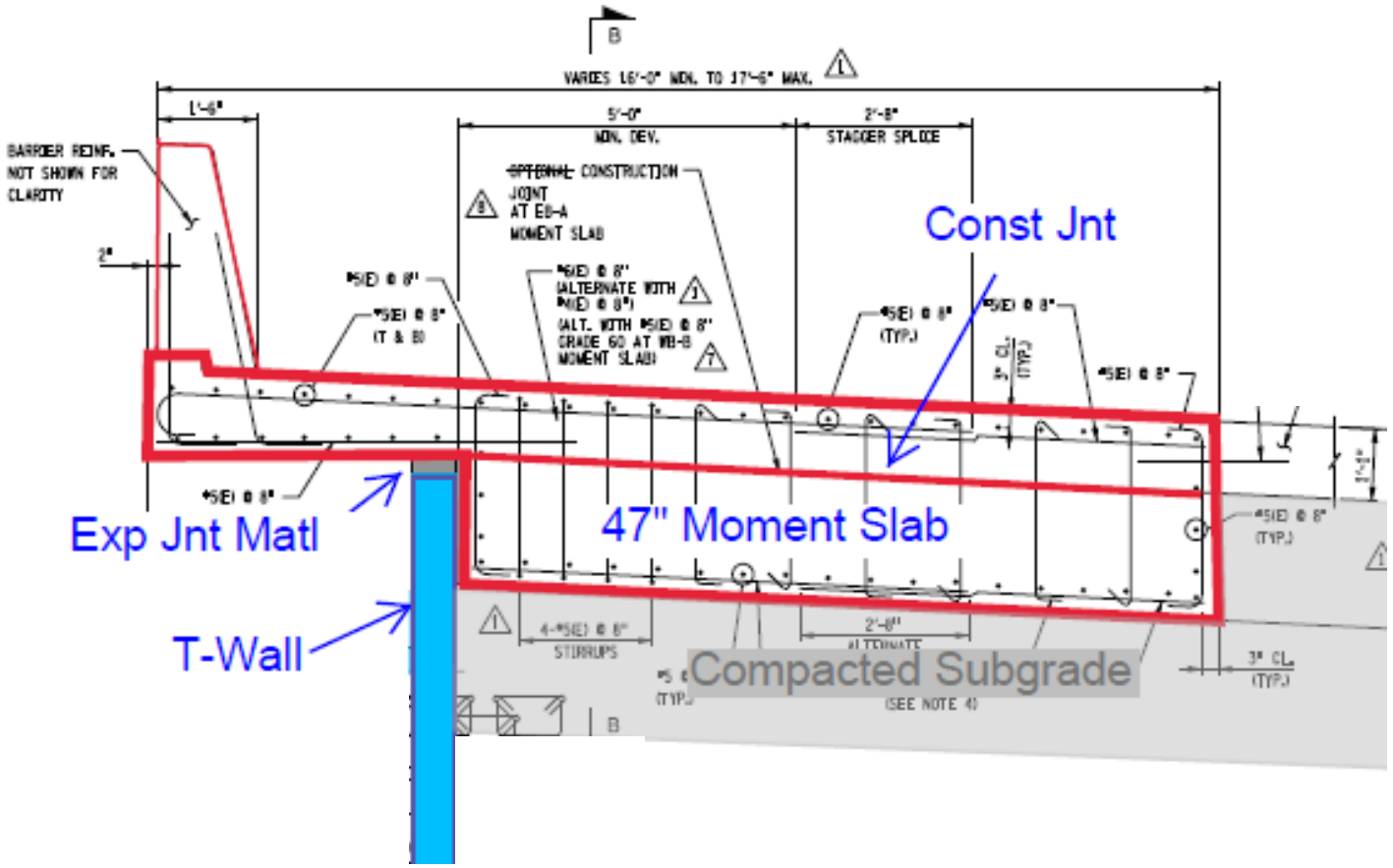


Connector Roadway – Moment Slabs

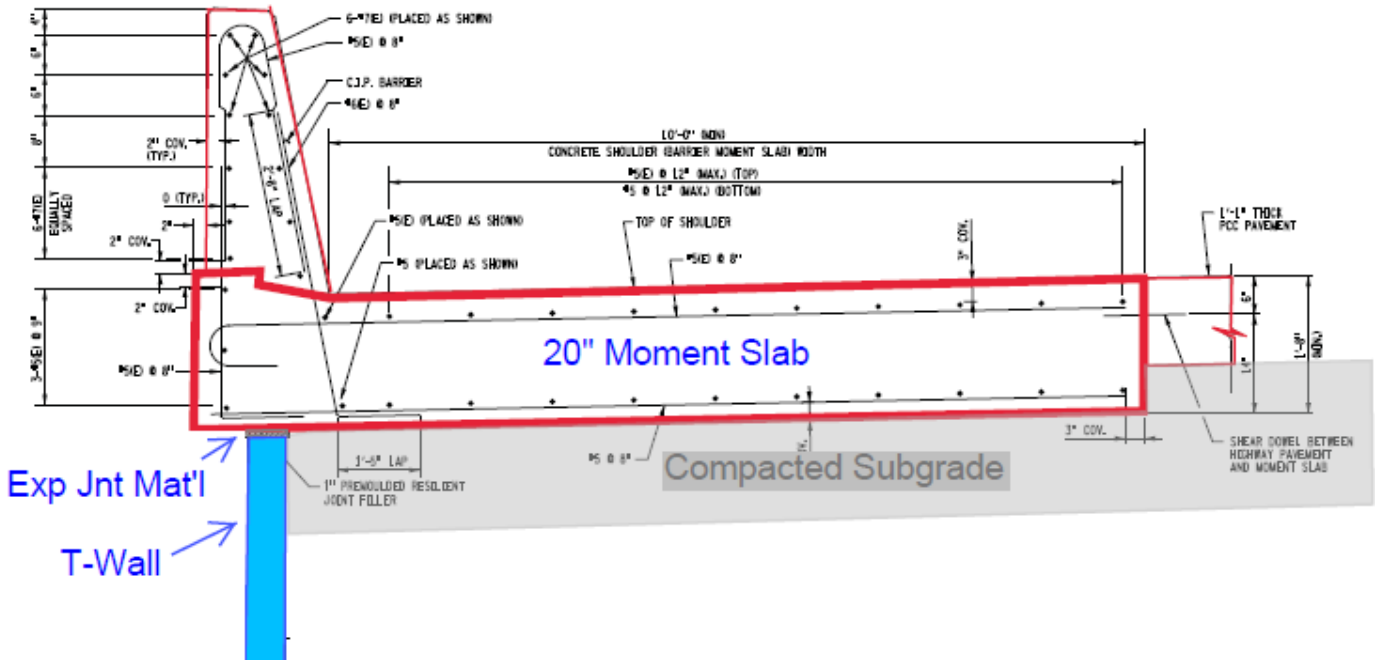
- Brooklyn Connector Cantilever Slabs Adjacent to T Walls
- HP Mix required – 75 year life - Epoxy Bar



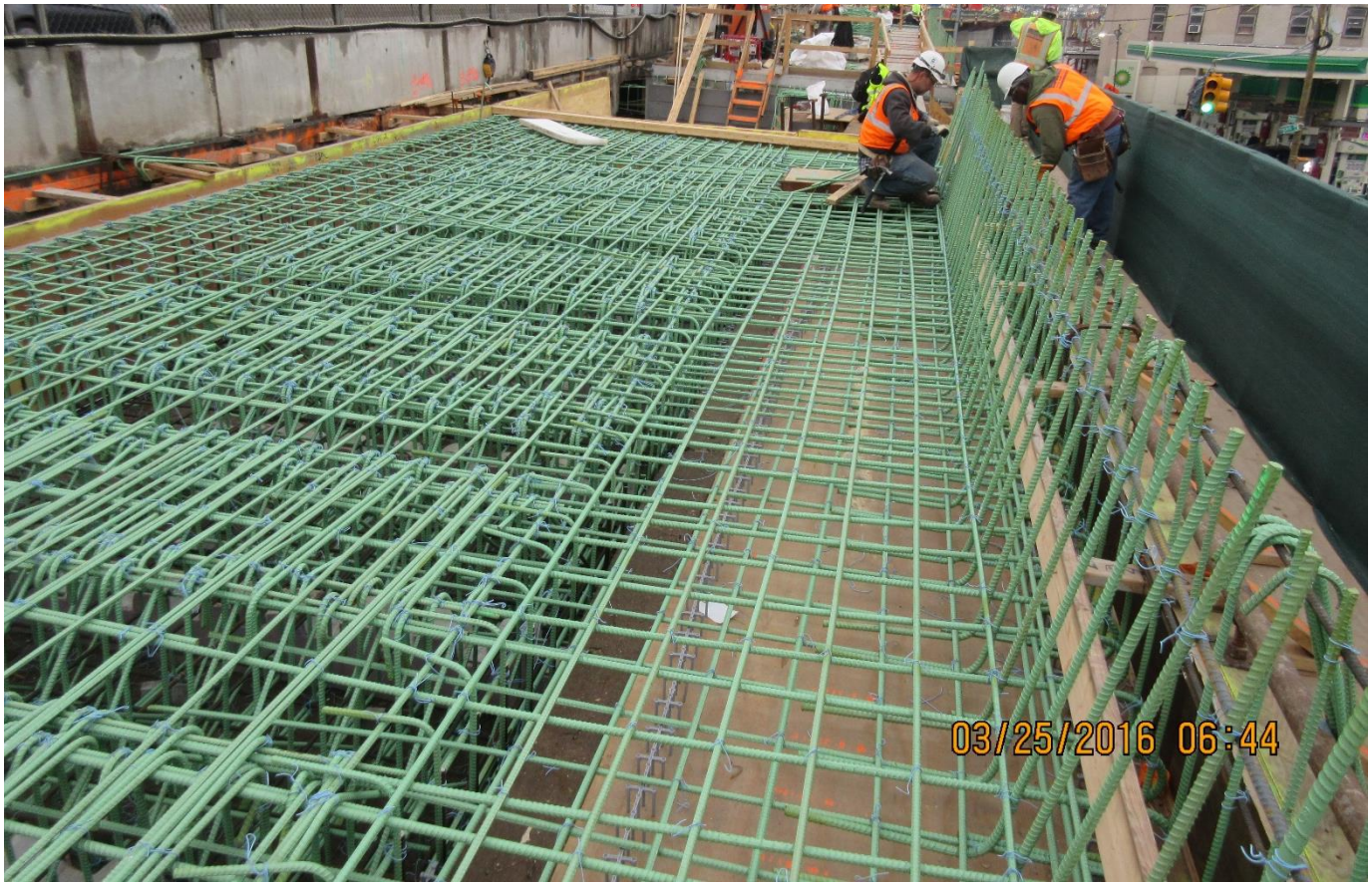
Connector Roadway – Moment Slabs



Moment Slab with Overhang



Moment Slab w/o Overhang



Moment Slab with Overhang

Moment Slab with Overhang

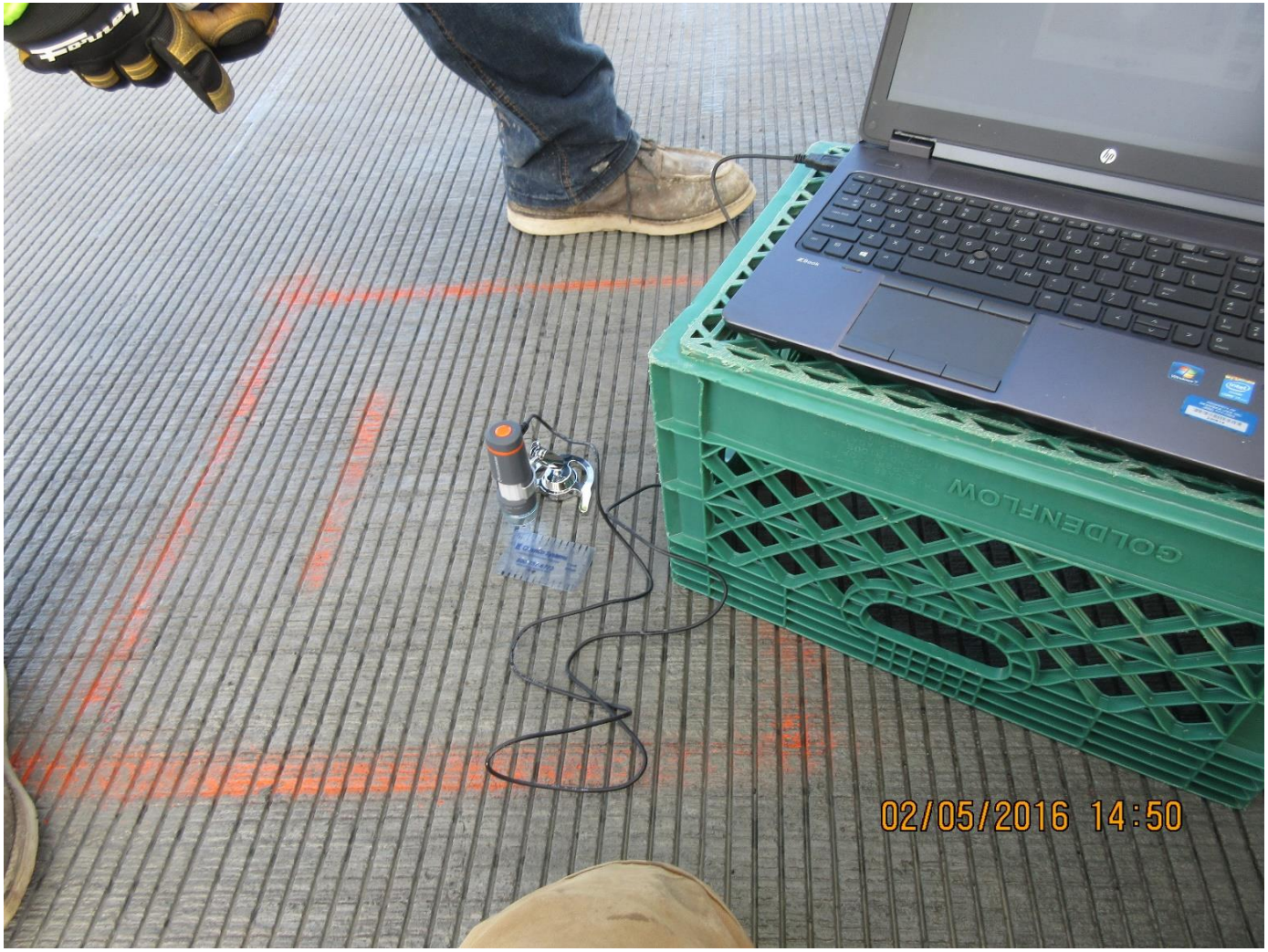
Moment Slab w/o Overhang

To evaluate cracks

- Accurate measurements needed
- High construction traffic areas precluded use of tell tale gauges
- Photographic documentation helpful
- Monitoring for stability against growth and movement
- Baseline for width estimation without measuring every crack
- Coring was not desirable
- Provide information to owner

1. Wallet Crack Gauge

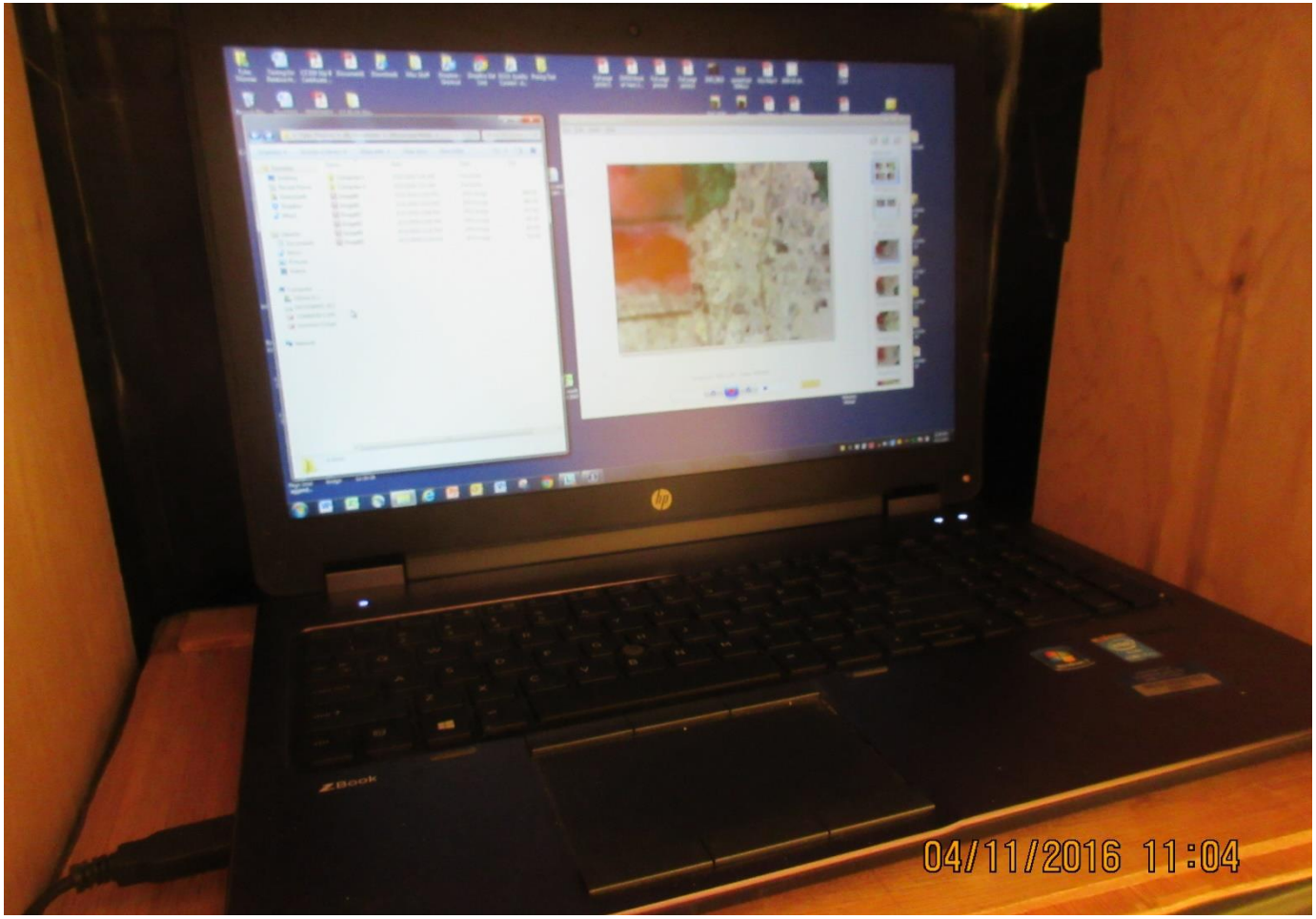
2. Specialized Crack Microscope with Scale



3. Digital Microscope with Laptop

4. Digital Microscope with “Review Booth”

Digital Microscope with Wallet Crack Gauge



“Review Booth”

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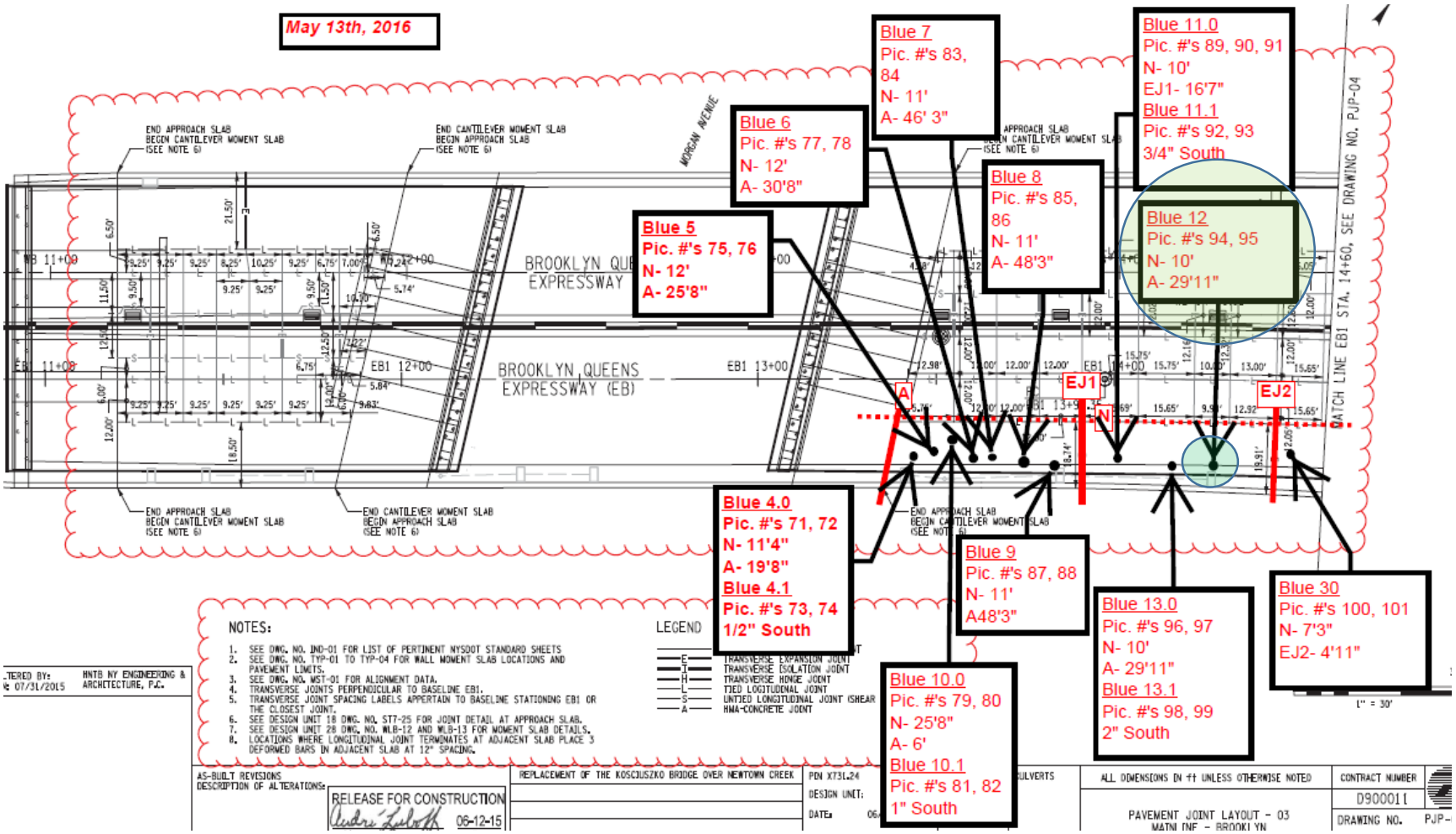

Crack Survey Map – Moment Slabs

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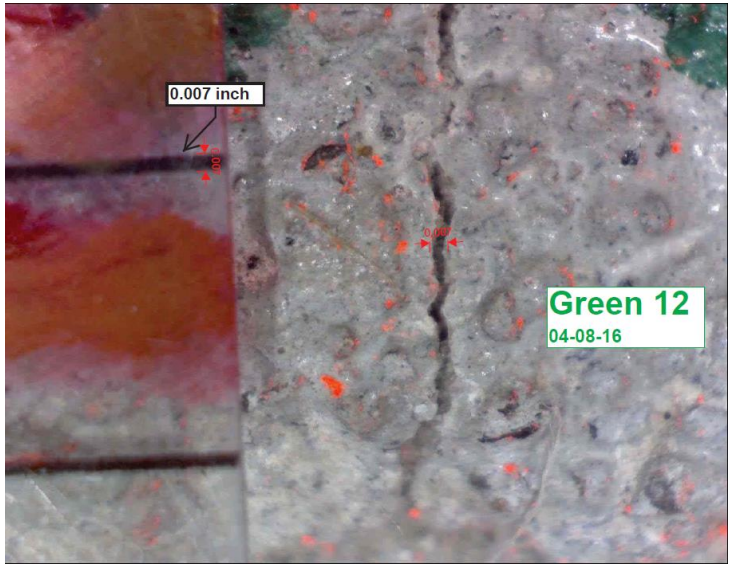
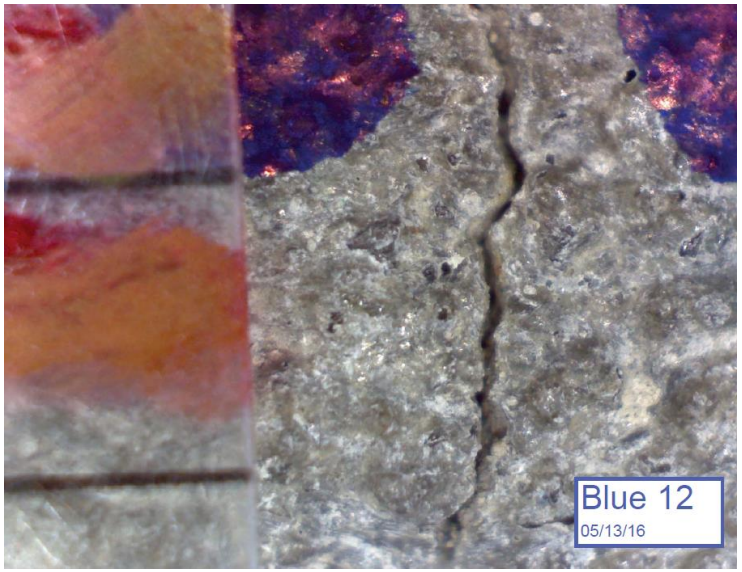
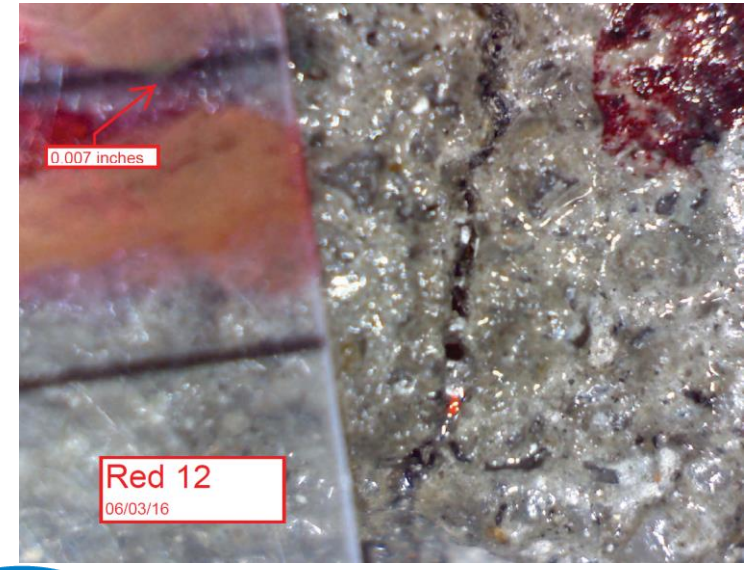






Crack #12 on three separate dates to confirm stability.

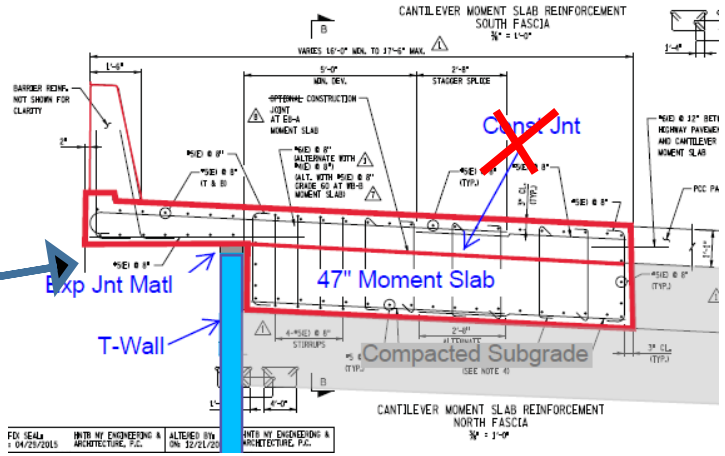
Moment slabs – Moving forward

For all slabs

- Seal all cracks over .007”
- Full dose of water
- Fogging and quickly placed curing covers
- Minimize placement temperatures

For cantilever moment slabs –

- Pour in one operation
- Use Mass Mix (70% slag) for deep section
- Use HP mix for the top.
- Monitor temperature of both layers



Approach Spans

(Brooklyn shown – Queens similar)

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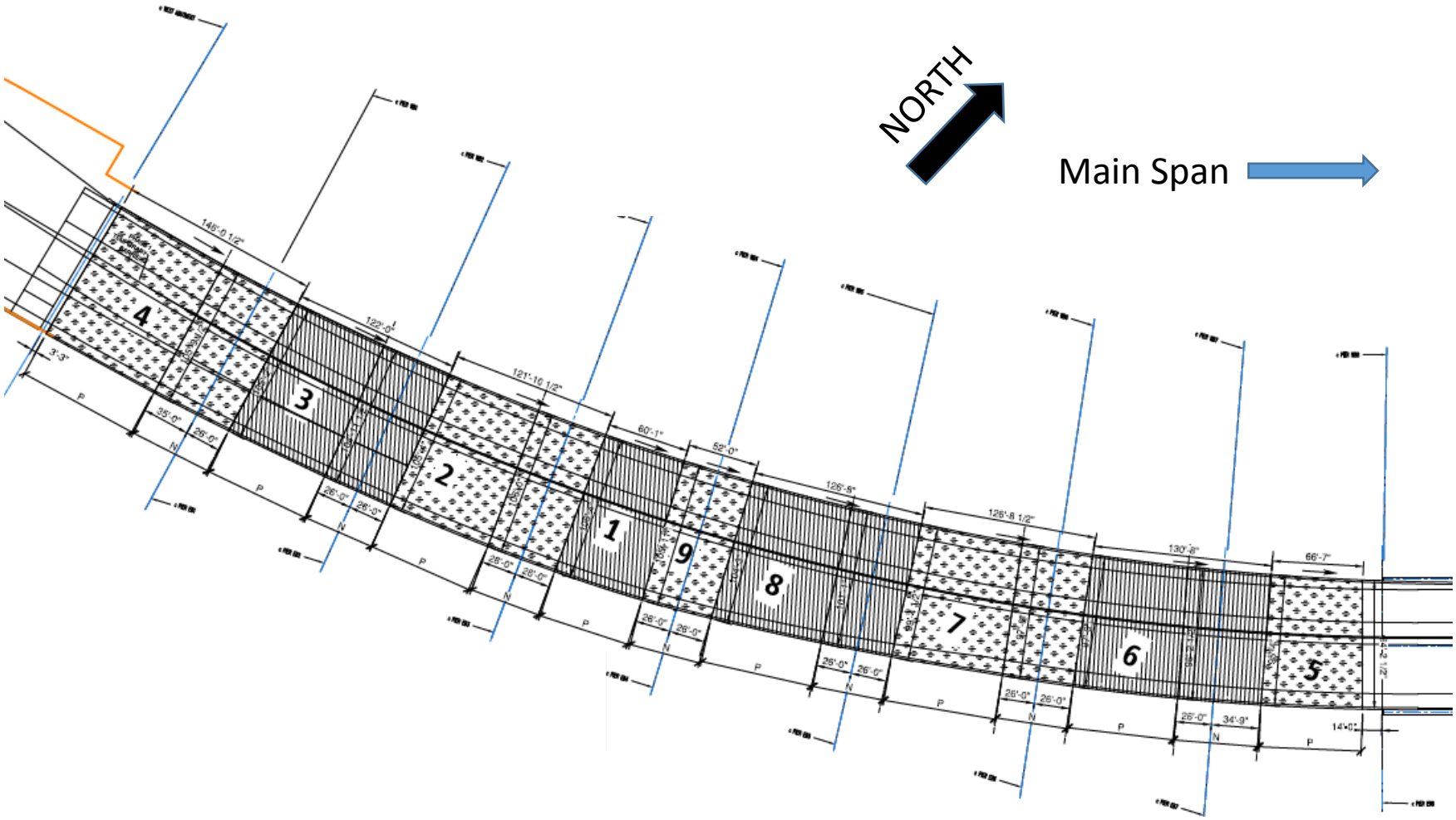
Approach decks - Challenges

- 1000’ of 8.5 inch deck on each side of Main Span
- #4’s SS @ 8” T & B – Both ways w/ add bars – 2” cover
- Placements to be average of 100’ by 100’
- Work to take place in the summer months
- Decks 60 to 80 feet off the ground with no wind blockage

Approach decks - Benefits

- Placements to be average of 100’ by 100’ (good aspect ratio)
- Minimum of restraint in decks (AASHTO girders with #5 shear ties at 12”)



Brooklyn Approach Decks Placement – (Queens Similar)

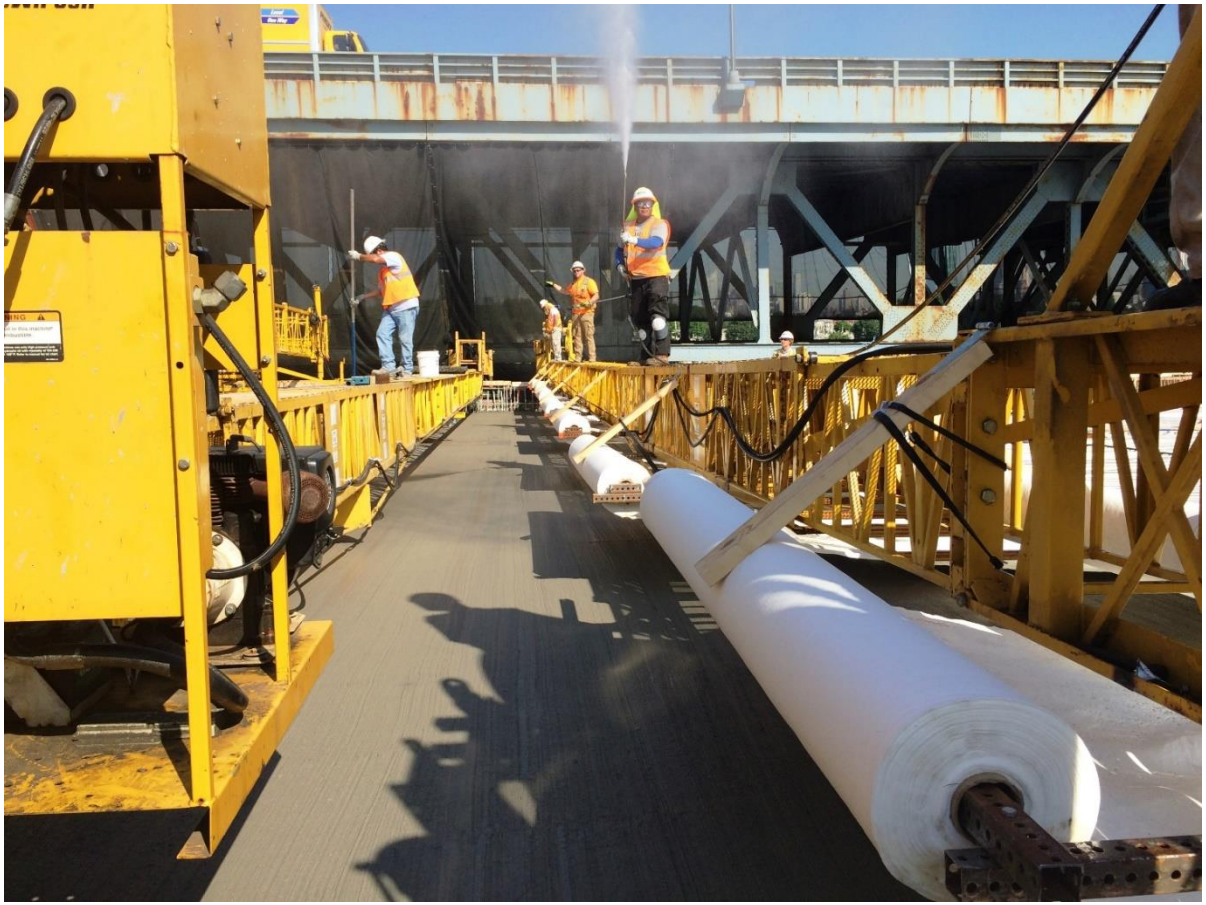
Positive Aspect

Approach Decks have minimal restraint.

Approach decks – Adjustments to Make

- Put all the water in
- Retarder and ice.
- Use two Bidwell carriages on one Truss for speed
- Fogging - via manifold and power washer
- Evaporation retarder considered
- Tune Bidwell so no floating required
- Masons – no blessing allowed
- Sophisticated one-use curing covers on roll-out bars
- Wet as only req'd – no flooding (thermal shock) (ACI 308)

Approach Span Roll-out Curing Covers



Roll-out Curing Covers

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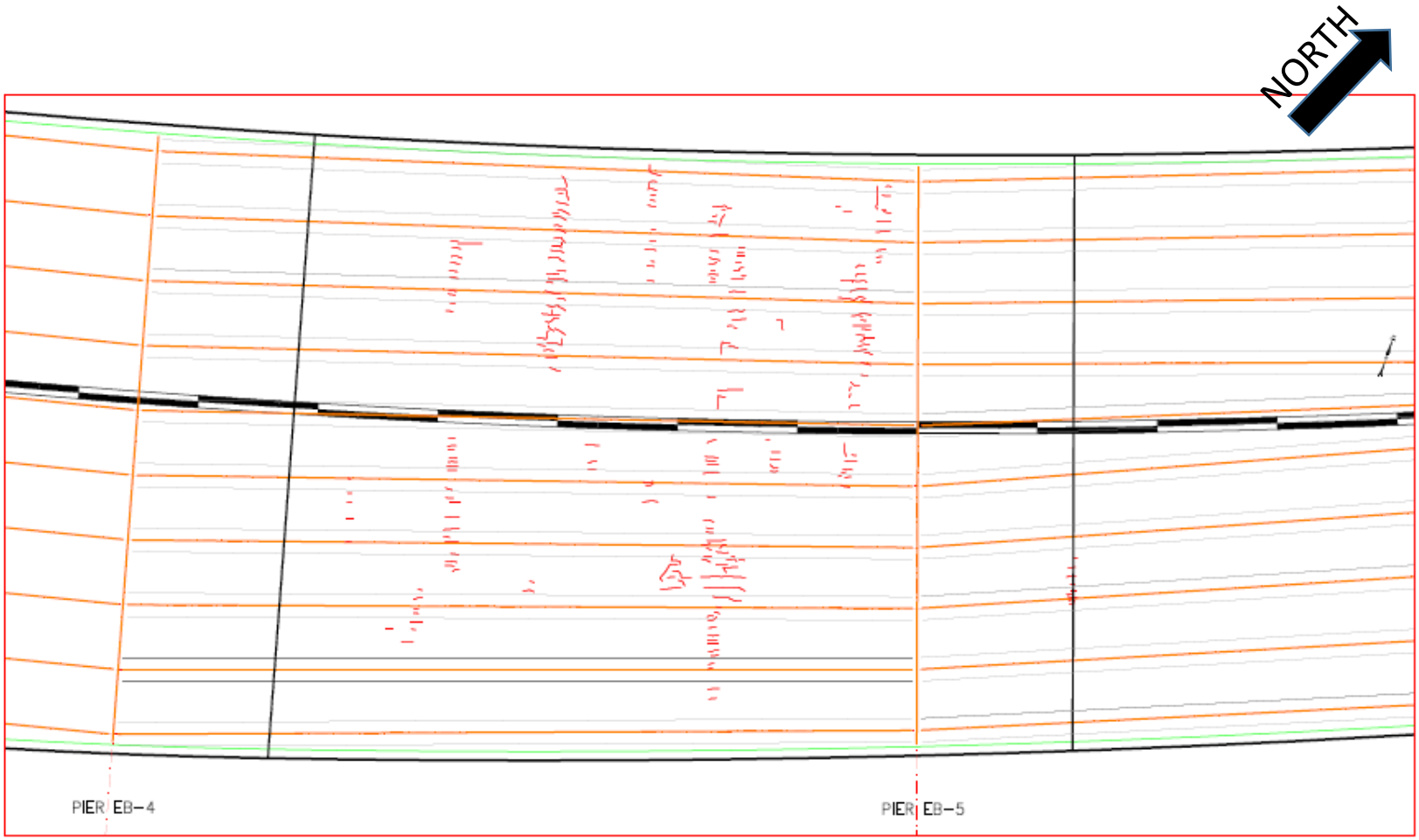
Bidwell with Fogging Manifold

Roll-out Curing Covers



PLACEMENT 8 – SPAN 5 CRACK MAPPING

Placement 8 – Span 5

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Options for NDT to Determine Crack Depths

- Ground Penetrating Radar to locate reinforcing
- Ultrasonic Pulse Velocity (UPV)
- Impact Echo Testing

Shortcomings

- Difficulties with congested reinforcing
- More reliable if calibrated against cores

Span 5

Span 5 with Rebar Detector

Dark Gray Silica Fume

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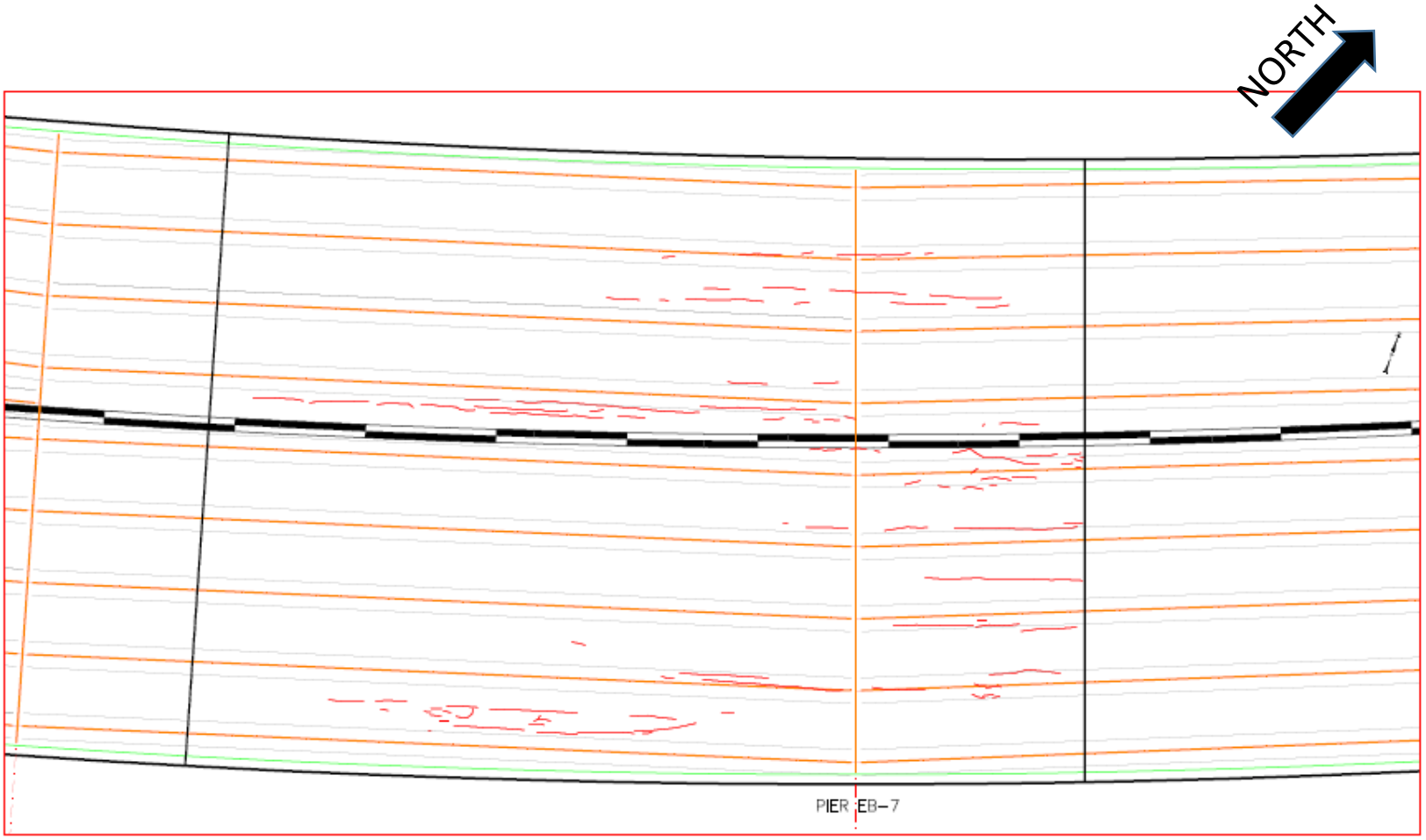
Evaluate Span 5 - Placed 5/26/16

- Exhibiting short parallel cracking across the deck
- Areas appear dark gray when wet
- Rebar detector shows the cracks to be directly over the rebar.
- Plastic shrinkage cracks most likely - improper mixing - high concentrations of silica fume.
- No bleed water, so not likely settlement cracks
- It is unlikely they are full depth cracks.

Repair

- Those over .007” sealed with MMA
- Follow with two coats Silane sealer



PLACEMENT 6 – SPAN 7, 8 CRACK MAPPING

Placement 6 – Span 7 and 8


06/16/2016 09:14


06/16/2016 09:13


06/16/2016 09:17

Evaluate Span 7 - Placed 5/16/16

- Exhibiting longitudinal continuous cracks spaced 8’ apart, (same as the width of the curing covers)
- Cracks not in line with the AASHTO girders below.
- Single use natural cellulose fiber covers with perforated plastic membrane were replaced with re-useable nonwoven polypropylene covers with non perforated plastic membrane.
- This indicates they are plastic shrinkage cracks due to the covers not being properly wetted and blown off at the side laps
- It is unlikely they are full depth cracks.

Repair

- Those over .007” sealed with MMA
- Follow with two coats Silane sealer

The Takeaway

1. Consider lower compressive strengths
2. Consider lower content of silica fume – if service life will still be OK
3. Account for restraint and aspect ratio
4. Add all the water to the mix. Account for absorption of SSD stone.
5. Keep placement temperatures low.
6. Use fogging. No blessing by the masons.
7. Let the Bidwell do the work. Don't over-work the surface.
8. No bull floating.
9. Place high quality cure covers ASAP - watch drying rates.
10. Use evaporation retarders if you can control the masons' use of it.
11. Wet cure without flooding to avoid thermal shock. (ACI 308)
12. Don't over heat the deck. Use low heat if necessary for winter work.
13. Call in experts for advice
14. Communicate with the customer
15. Consider LW sand in mix or shrinkage compensating admix

Questions and Comments