# Puerto Rico Construction Industry

## *Acceptance of Concrete*

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SEGARRA
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# SEMINARIO de la BECA

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APC
ASOCIACIÓN PUERTORRIQUEÑA DEL CONCRETO

THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE

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# Agenda

- Construction Specifications
- Quality Control and Quality Assurance
- Acceptance of Concrete
- QC Plan
- Lessons learned
  - Maturity Testing
  - Mass Concrete Temperature Control

# Contract Documents

- Plans
- Technical Specifications
- Legal part
- Ensure that the quality of the workmanship, control of the tolerances and/or materials necessary to carry out and finish the work comply as specified and will be performed according to the designer's intention.

# Construction Specifications

- Establish acceptance parameters
- They should be easy to understand
- They can be prescriptive and/or performance-based
- They provide the guidelines for:
- Materials
- Construction methods
- Methods for Measuring Compliance with Specifications
- Testing Requirements
- Payment basis for each item

# Quality and Profit

- The Contractor may pay for the cost control of a quality control system to provide an appropriate level of quality
- The Contractor may pay for the lack of control of costs associated with poor quality
- Repairs
- Patching in unacceptable areas
- Removal and/or replacement of work
- Time impact on construction schedule
- High litigation costs


THINK
QUALITY
DO IT RIGHT THE FIRST TIME
WE DON'T ALWAYS GET A
SECOND CHANCE

# Pre-Construction Meeting - QC/QA

A meeting between QC and QA representatives before construction begins:

- Review Project Requirements
- Review the action and/or suspension limits of activities
- Identify and clarify any mismatches or articles that are ambiguous
- Review the handling of test results that are Non-Compliant
- Review the chain of command for decision-making
- Establish a QC/QA plan for data review and management
- Project Manager Engineer, Owner/Administrator, Owner's Representative, QC Manager, Contractor, Sub-Contractors, Testing Labs

# Cost of Poor Quality

- **What Means For the Project Owner/Manager?**
  - Loss of income
  - Operational delays
  - Reduction in the useful life of the structure
- **What Means For the Contractor?**
  - Corrective actions
  - Partial payments (discounts)
  - Cost of claims
  - Liquidated damages

# What to Know Before Placing Concrete?

- Tolerances – ACI 117
- Reinforcing steel installation
- Sizes, position, spacing, ties, quantity according to shop drawings, splice, etc.
- Cover of concrete and formwork design
- Distance perpendicular to the face of the exposed surface according to the structure or exposure (forms, soil, etc.)
- Soil Conditions, compaction, moisture barriers
- Forms, position, plumb line, safe to resist pressure

# Design Guides & Specifications

- **Comprehensive Communication**
  - Owner
  - Designer
  - Structural Engineer
  - Architect
  - Constructor
  - Concrete Producer
- **Prescriptive vs. Prescriptive Specifications Performance**
- **Predict**
  - Location – Available Materials
  - Labor – Capacity/Skill
  - Equipment necessary to execute the work
- **Tolerances during construction**

# Concrete Specifications

- ACI 318, ACI 301, ACI 305, ACI 311, ASTM C94
- Compressive Strength (mechanical property)
- Slump (workability, easy adjustment, consolidation)
- Temperature (hydration of cement, hot weather)
- Density or Unit Weight (yield, material control)
- Air Content (durability, workability)
- Water/Cement and/or Water/Cementitious Ratio

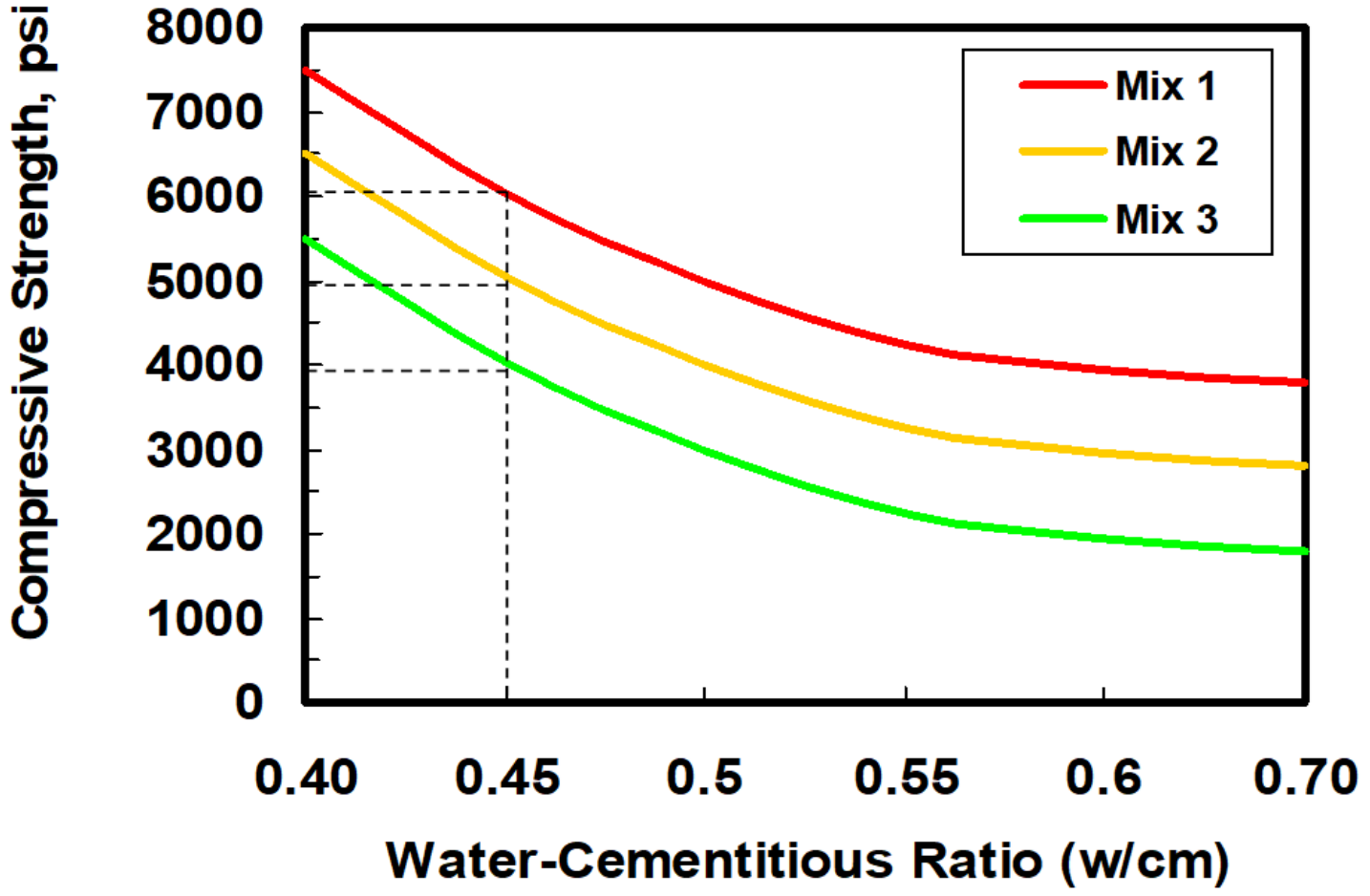
# Example – W/C Ratio & Slump

**Slump = 1/2”**
**W/C=0.55**

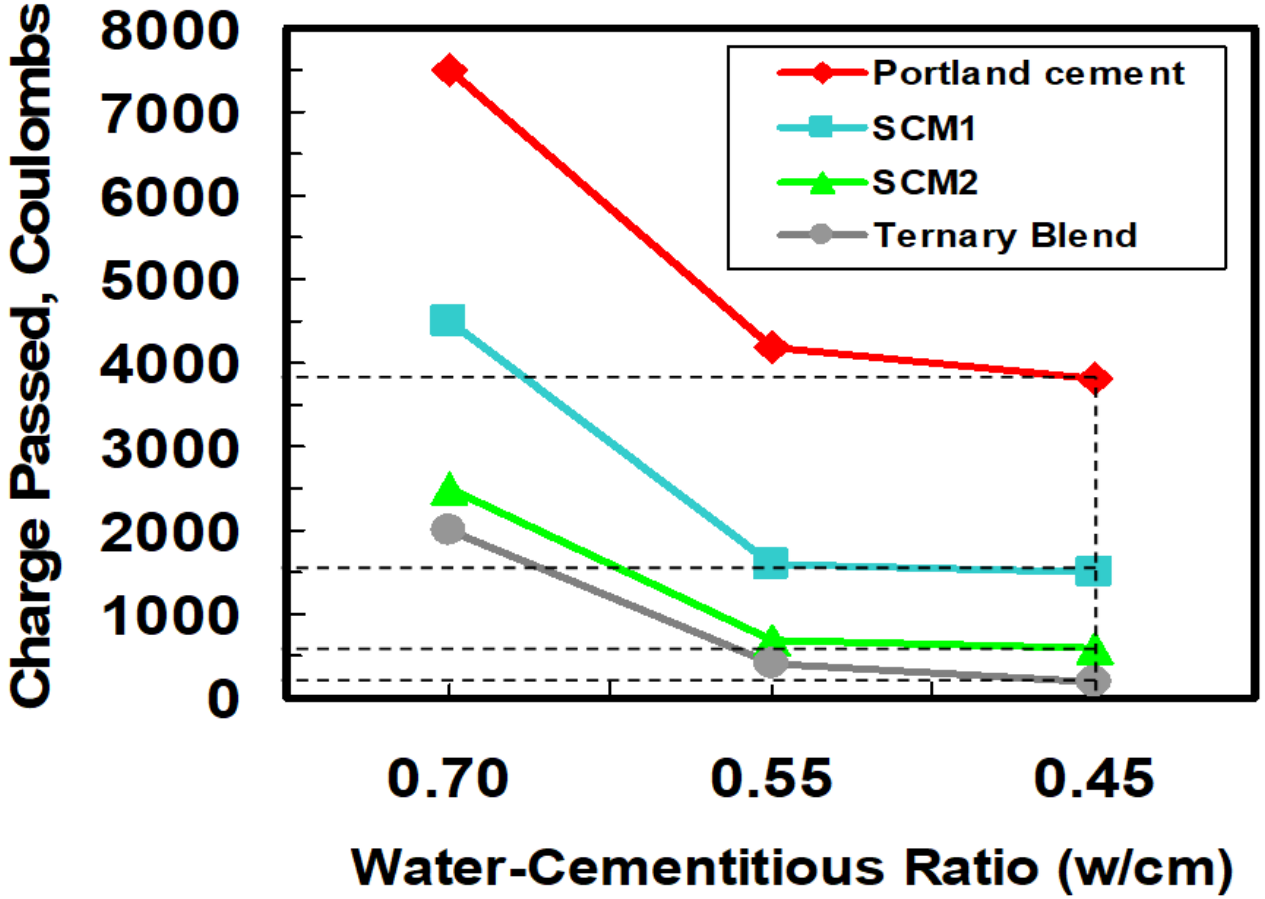
**Slump = 5.5”**
**W/C=0.65**

# Example – W/C Ratio & Slump

# Example – W/C Ratio: Compressive Strength



# Example – W/C Ratio: Durability



# Effect of Aggregates

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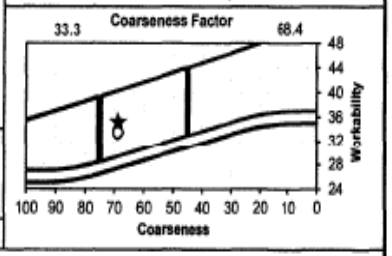
Design PSI ($f'_c$): 650 | Design Slump: 1.5 - 3 | Location: San Juan PR | Placement: Truck | Agg. Gradation Limits: #4 ACI 302-04 (22-8)

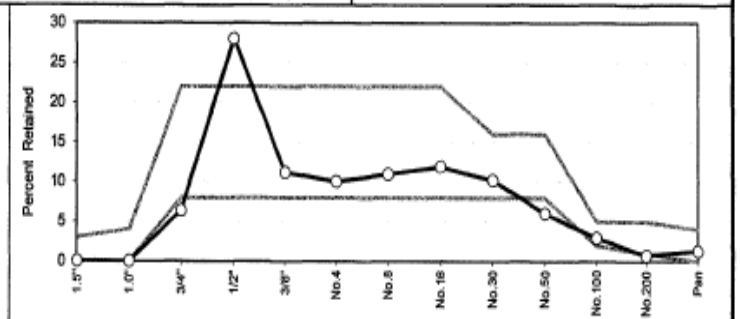
Slipform
San Juan Airport
Combination 635

| Cementitious Materials | Weight Lbs | Abs. Vol. Cu.Ft. | % Vol. | | Cost |
|---|---|---|---|---|---|
| Essroc PR | 635 | 3.23 | 100.0 | | $47.09 |
| | | - | | | $0.00 |
| | | | | | $0.00 |
| | | | | | $0.00 |
| **Total Cementitious** | 635 | 3.23 | | Cmt Cost | $47.09 |
| EOB 4 PR | 0 | | | | |
| EOB 67 PR | 1900 | 11.03 | 59.7% | | $14.25 |
| Arenero Rafael | 275 | 1.69 | 9.1% | 0.23 | $1.38 |
| Concretos River Sand | 925 | 5.75 | 31.1% | 0.77 | $4.63 |
| | | | | | |
| Design Air Content | 4.0 | 1.08 | | Agg Cost | $20.25 |
| Water: 32.4 Gal | 270 | 4.33 | | Water Cost | $0.00 |
| | | | | Fiber Cost | $0.00 |
| **Total:** | **4005** | **27.10** | | **Total Cost** | **$69.03** |

| Admixture | Oz/yard | oz / cwt |
|---|---|---|
| AEA | 5.40 | 0.85 |
| Water Reducer | 19.05 | 3.00 |
| Retarder | 19.05 | 3.00 |
| Accelerator | | - |
| | | - |
| | | - |
| Admixture Cost/ Volume | $1.70 | |




| | |
|---|---|
| Plastic Density - Cu.Ft. | 147.77 |
| Paste Fraction | 27.9% |
| Paste Fraction + Air | 31.9% |
| Mortar Fraction | 54.5% |
| Air Vol / (Cementitious + water) | 14.3% |
| Sand / Agg ratio (Vol) | 0.40 |
| Workability Factor (fines) | 33.3 |
| Coarseness Factor: | 68.4 |
| W-Adj (Workability-Adjustment) | 35.2 |
| O.I.F | 1493 |
| Vol Water / Vol Cemt | 1.339 |
| Water/Cementitious Ratio | 0.425 |




Combined Agg. Blend FM= 5.35 FM of Blended Sands 3.381



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# Selection of Proportions

# Aggregates - ASTM C33

**TABLE 3 Grading Requirements for Coarse Aggregates**

| Size Number | Nominal Size (Sieves with Square Openings) | Amounts Finer than Each Laboratory Sieve (Square-Openings), Mass Percent | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 mm (4 in.) | 90 mm (3½ in.) | 75 mm (3 in.) | 63 mm (2½ in.) | 50 mm (2 in.) | 37.5 mm (1½ in.) | 25.0 mm (1 in.) | 19.0 mm (¾ in.) | 12.5 mm (½ in.) | 9.5 mm (⅜ in.) | 4.75 mm (No. 4) | 2.36 mm (No. 8) | 1.18 mm (No. 16) | 300 µm (No.50) |
| 1 | 90 to 37.5 mm (3½ to 1½ in.) | 100 | 90 to 100 | ... | 25 to 60 | ... | 0 to 15 | ... | 0 to 5 | ... | ... | ... | ... | ... | ... |
| 2 | 63 to 37.5 mm (2½ to 1½ in.) | ... | ... | 100 | 90 to 100 | 35 to 70 | 0 to 15 | ... | 0 to 5 | ... | ... | ... | ... | ... | ... |
| 3 | 50 to 25.0 mm (2 to 1 in.) | ... | ... | ... | 100 | 90 to 100 | 35 to 70 | 0 to 15 | ... | 0 to 5 | ... | ... | ... | ... | ... |
| 357 | 50 to 4.75 mm (2 in. to No. 4) | ... | ... | ... | 100 | 95 to 100 | ... | 35 to 70 | ... | 10 to 30 | ... | 0 to 5 | ... | ... | ... |
| 4 | 37.5 to 19.0 mm (1½ to ¾ in.) | ... | ... | ... | ... | 100 | 90 to 100 | 20 to 55 | 0 to 15 | ... | 0 to 5 | ... | ... | ... | ... |
| 467 | 37.5 to 4.75 mm (1½ in. to No. 4) | ... | ... | ... | ... | 100 | 95 to 100 | ... | 35 to 70 | ... | 10 to 30 | 0 to 5 | ... | ... | ... |
| 5 | 25.0 to 12.5 mm (1 to ½ in.) | ... | ... | ... | ... | ... | 100 | 90 to 100 | 20 to 55 | 0 to 10 | 0 to 5 | ... | ... | ... | ... |
| 56 | 25.0 to 9.5 mm (1 to ⅜ in.) | ... | ... | ... | ... | ... | 100 | 90 to 100 | 40 to 85 | 10 to 40 | 0 to 15 | 0 to 5 | ... | ... | ... |
| 57 | 25.0 to 4.75 mm (1 in. to No. 4) | ... | ... | ... | ... | ... | 100 | 95 to 100 | ... | 25 to 60 | ... | 0 to 10 | 0 to 5 | ... | ... |
| 6 | 19.0 to 9.5 mm (¾ to ⅜ in.) | ... | ... | ... | ... | ... | ... | 100 | 90 to 100 | 20 to 55 | 0 to 15 | 0 to 5 | ... | ... | ... |
| 67 | 19.0 to 4.75 mm (¾ in. to No. 4) | ... | ... | ... | ... | ... | ... | 100 | 90 to 100 | ... | 20 to 55 | 0 to 10 | 0 to 5 | ... | ... |
| 7 | 12.5 to 4.75 mm (½ in. to No. 4) | ... | ... | ... | ... | ... | ... | ... | 100 | 90 to 100 | 40 to 70 | 0 to 15 | 0 to 5 | ... | ... |
| 8 | 9.5 to 2.36 mm (⅜ in. to No. 8) | ... | ... | ... | ... | ... | ... | ... | ... | 100 | 85 to 100 | 10 to 30 | 0 to 10 | 0 to 5 | ... |
| 89 | 9.5 to 1.18 mm ( ⅜ in. to No. 16) | ... | ... | ... | ... | ... | ... | ... | ... | 100 | 90 to 100 | 20 to 55 | 5 to 30 | 0 to 10 | 0 to 5 |
| 9[A] | 4.75 to 1.18 mm (No. 4 to No. 16) | ... | ... | ... | ... | ... | ... | ... | ... | ... | 100 | 85 to 100 | 10 to 40 | 0 to 10 | 0 to 5 |

[A] Size number 9 aggregate is defined in Terminology C125 as a fine aggregate. It is included as a coarse aggregate when it is combined with a size number 8 material to create a size number 89, which is a coarse aggregate as defined by Terminology C125.

**TABLE 1 Grading Requirements for Fine Aggregate**

| Sieve (Specification E11) | Percent Passing |
|---|---|
| 9.5-mm (⅜-in.) | 100 |
| 4.75-mm (No. 4) | 95 to 100 |
| 2.36-mm (No. 8) | 80 to 100 |
| 1.18-mm (No. 16) | 50 to 85 |
| 600-µm (No. 30) | 25 to 60 |
| 300-µm (No. 50) | 5 to 30 |
| 150-µm (No. 100) | 0 to 10 |
| 75-µm (No. 200) | 0 to 3.0[A,B] |

[A] For concrete not subject to abrasion, the limit for material finer than the 75-µm (No. 200) sieve shall be 5.0 % maximum.
[B] For manufactured fine or other recycled aggregate, if the material finer than the 75-µm (No. 200) sieve consists of the dust of fracture, essentially free of clay or shale, this limit shall be 5.0% for concrete subject to abrasion, and 7% maximum for concrete not subject to abrasion.

# On-Site Acceptance Tests

- Concrete sampling is just as important as the tests performed on it
- Competent, educated and certified staff
  - Ensure processes are done correctly
- They must understand the meaning of the results at the time of the tests
  - Slump Out of Tolerance, Unit Weight, Air Content Out of Tolerance, Temperatures Out of Bounds

# Technical Certifications Program

## Puerto Rican Concrete Association

- Concrete Field Testing Technician Grade 1
- Concrete Strength Testing Technician
- Aggregate Testing Technician Level 1
- Aggregate Base Testing Technician
- Concrete Construction Special Inspector

# Quality Control Program

- Create a plan where each person knows their role
- The time for details, clarifying doubts, discussion of the rules of the game, is days before the concrete placing operations.
- The day of the concrete placement is to execute in an acceptable way as planned.
- Use of concrete preplacement checklist

# Quality Control Program




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# Quality Control Program

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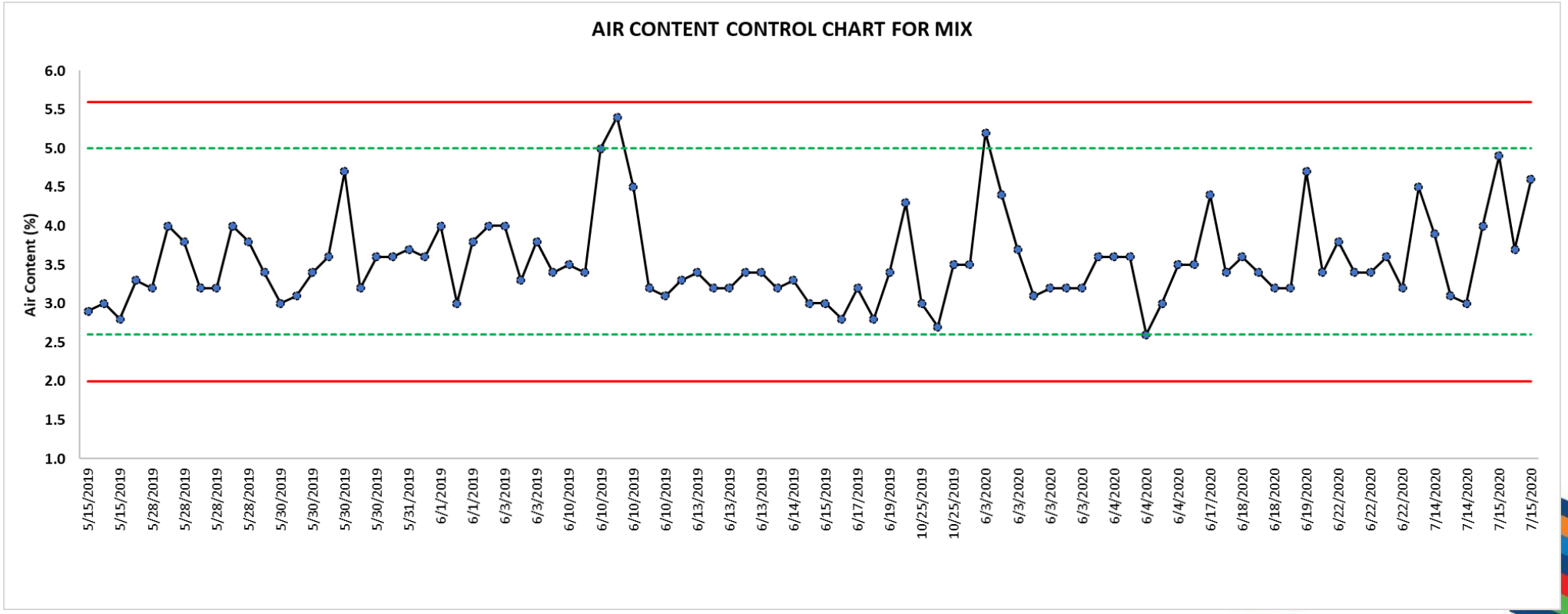
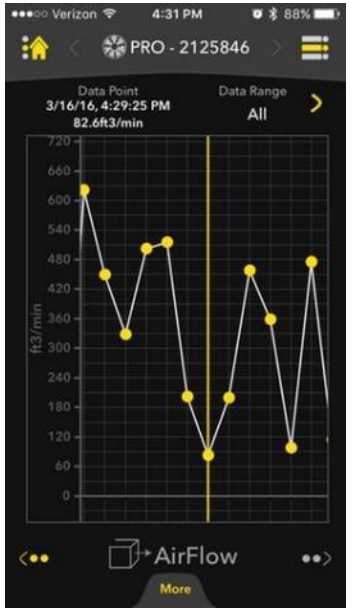
- Quality Control – Control Charts

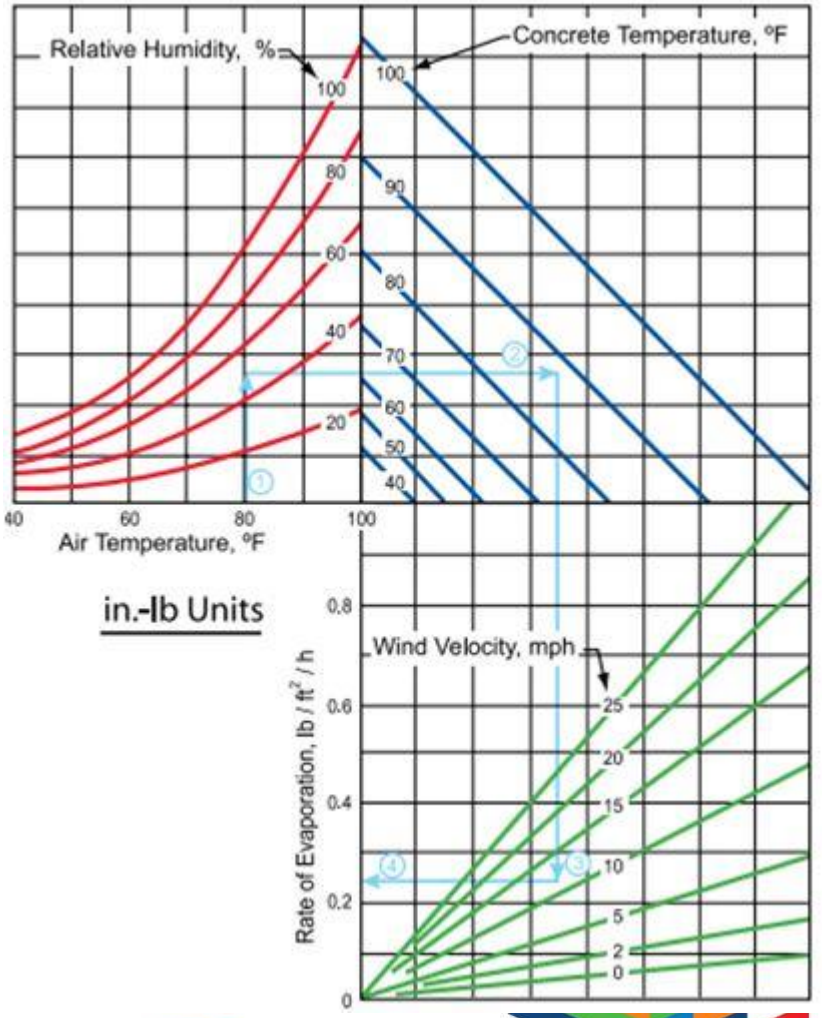


# Quality Control Program

- Monitor Evaporation Ratio, Environmental Conditions and Temperature of Concrete Mix







# Concrete Installation

# Concrete Curing

# Planning - Rain Events

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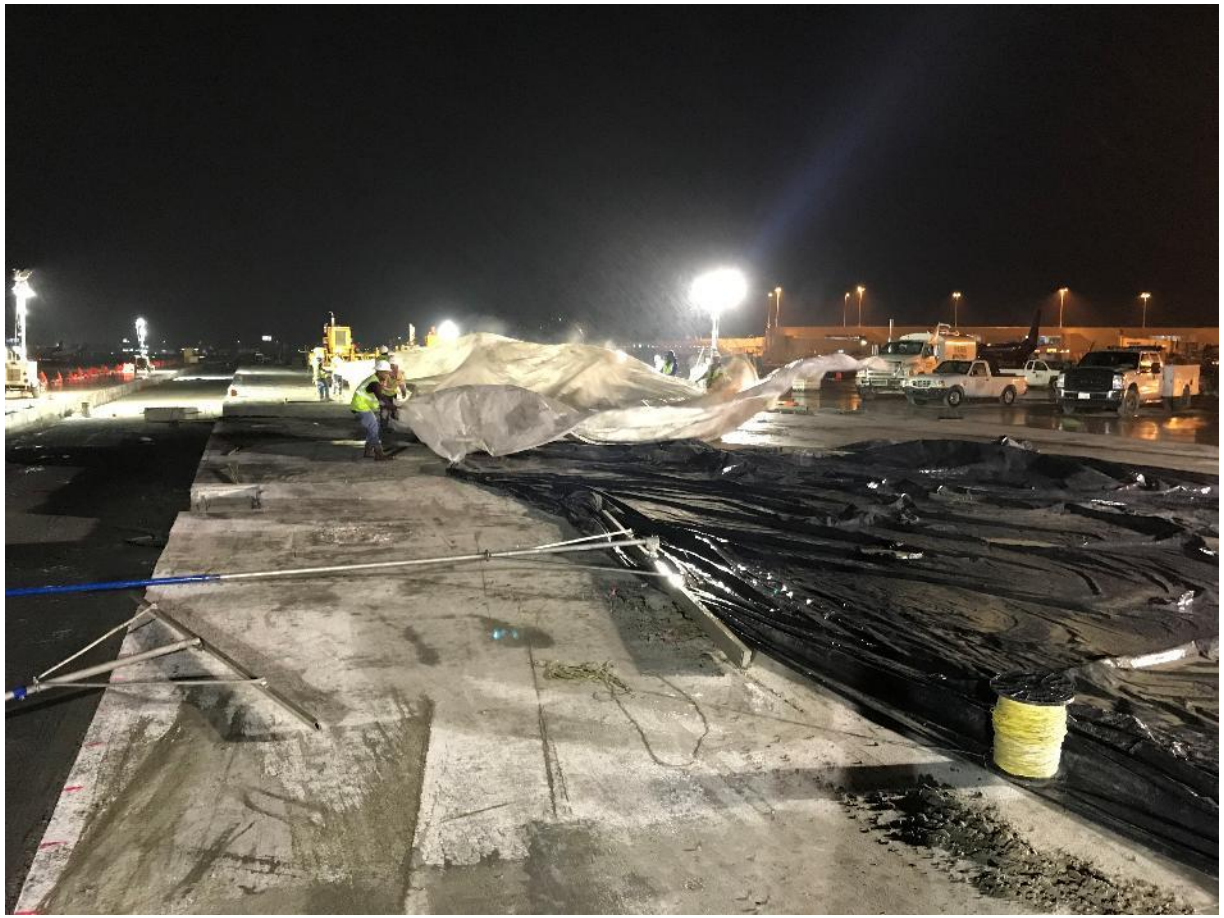
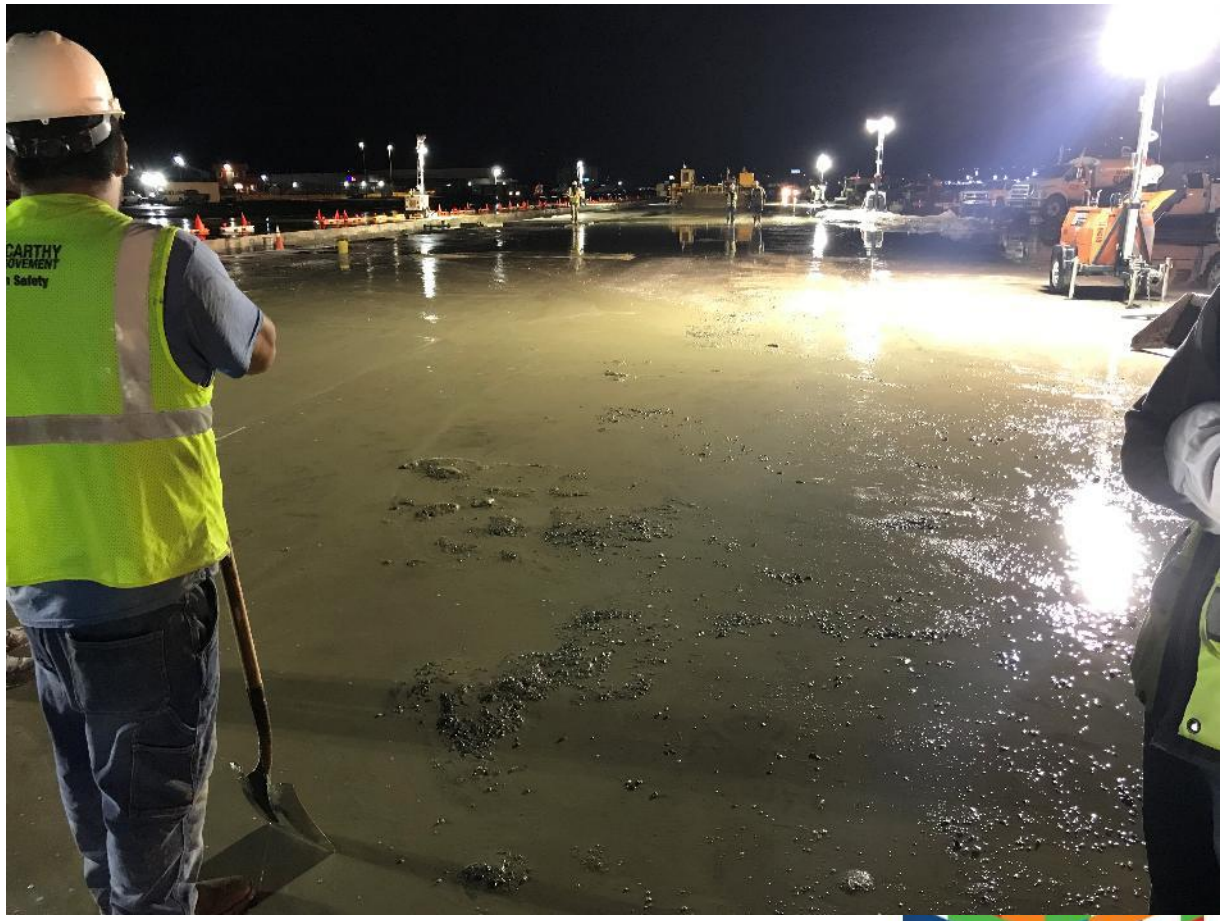
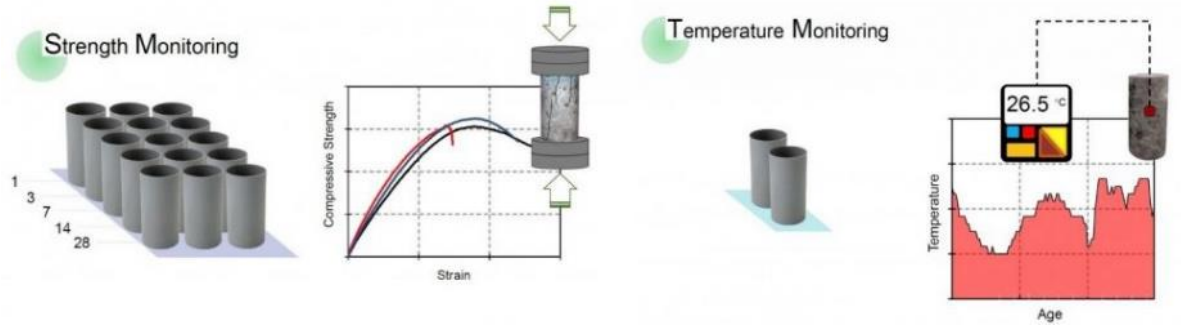
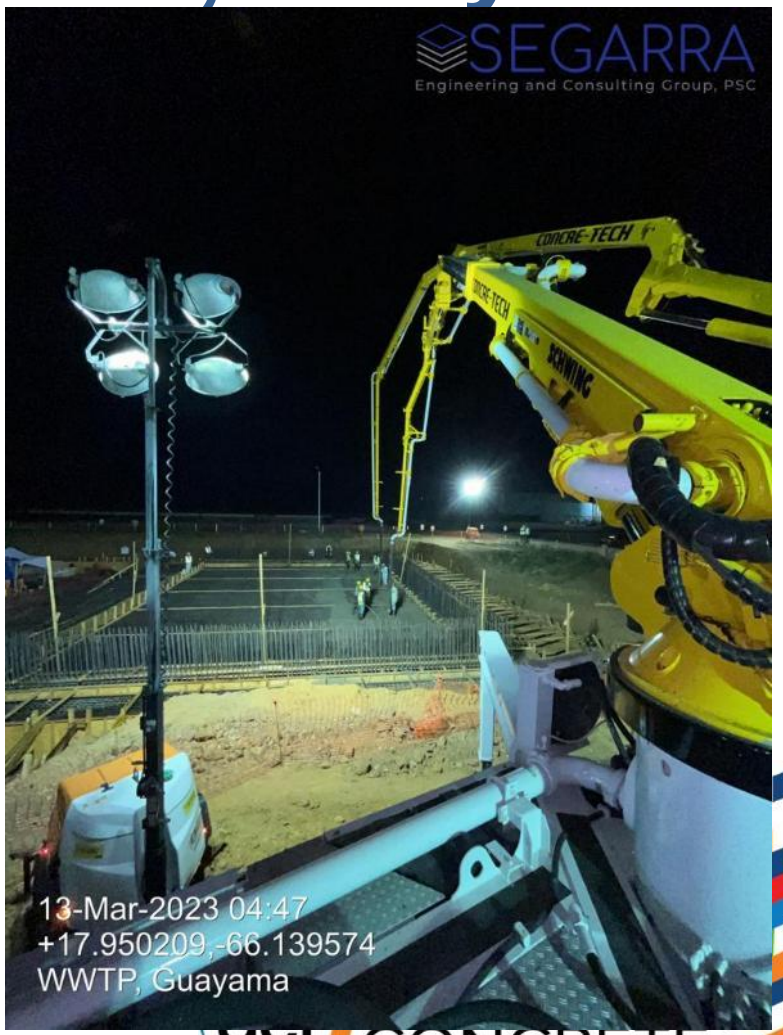




# Maturity Testing and Mass Concrete Control


# Mass Concrete Planning : WWTP, Guayama

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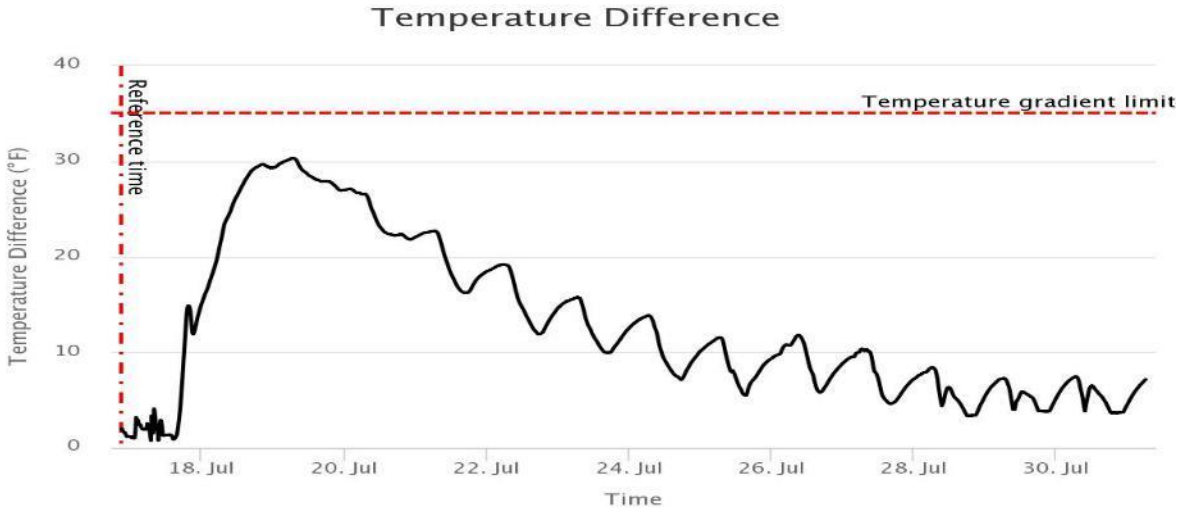


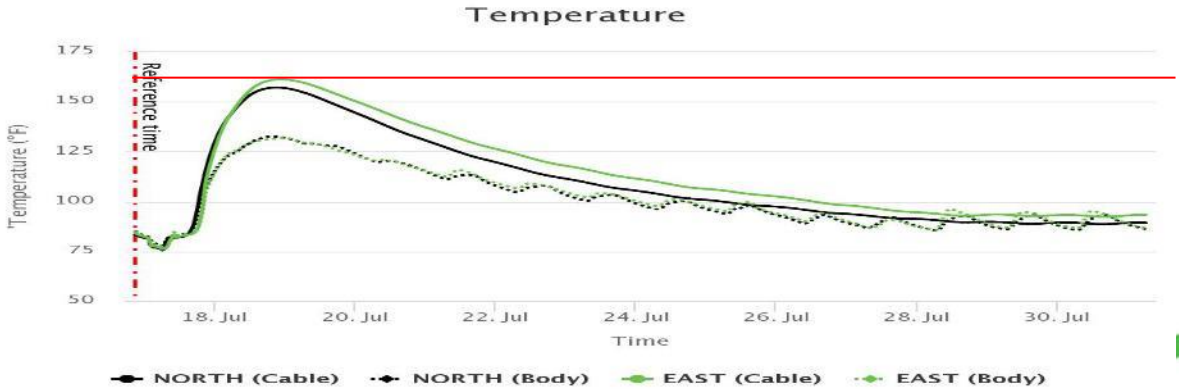

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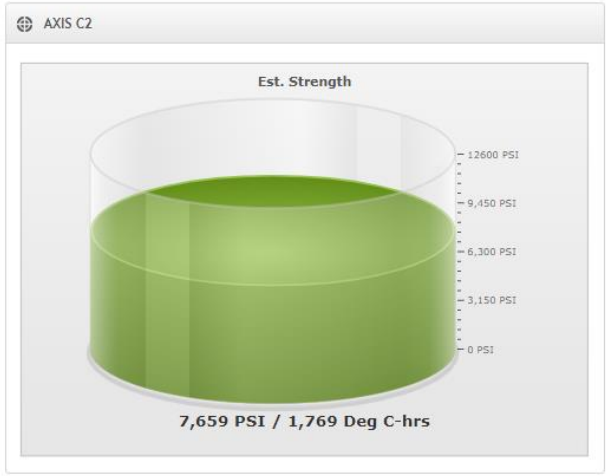
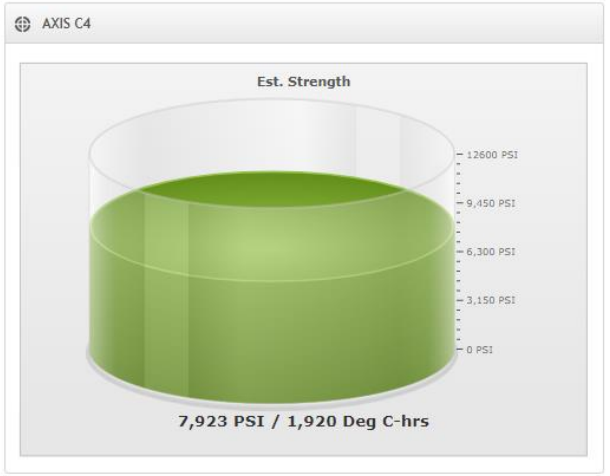
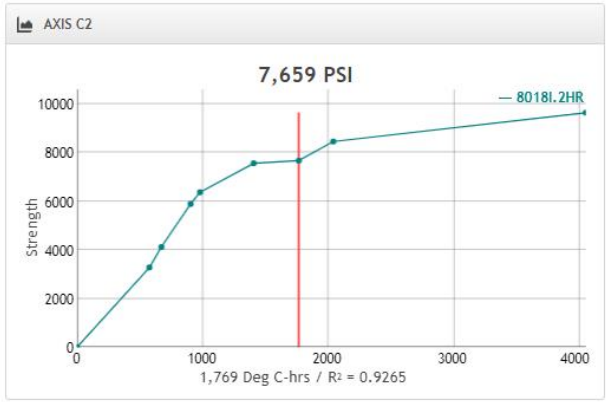
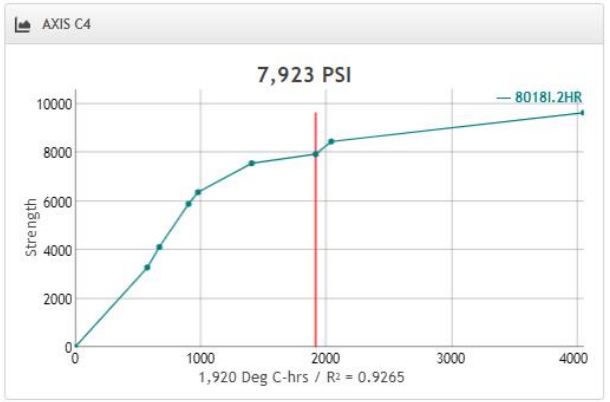


# LANDSLIDE REPAIR PR-10 FROM KM. 41.6 TO 41.9, UTUADO, PR

**Project Specs (934 Federal Land):**

- Class of Concrete: Class V (Bridge Element)
- Compressive Strength (28 days): 5,000 psi
- Permeability (Coulombs): 1,950
- Maximum Water Cementitious Ratio: 0.45
- Maximum Cementitious Content (lb/cy): 700 lb
- Shrinkage Reducing Admixture: 1 gal/cy
- Corrosion Inhibitor: 3 gals/cy
- Max. Delivery Temp: 85 °F

**Mass Concrete Specs:**

Max Temperature: 160 °F

Max Differential Temperature: 35 °F

# LANDSLIDE REPAIR PR-10 FROM KM. 41.6 TO 41.9, UTUADO, PR

**Concrete Mix:**

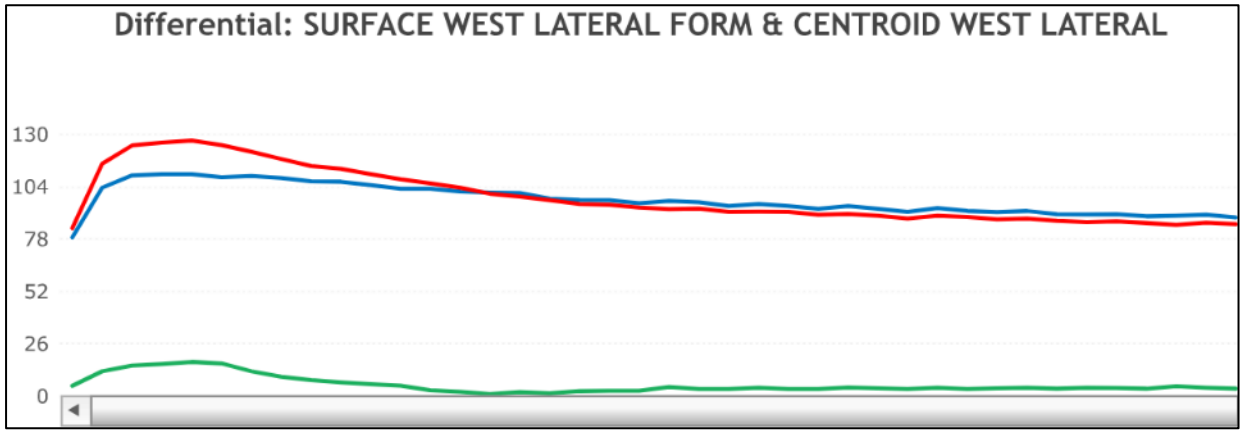
- Portland Cement: Type I/II
- 40 % Slag Cement
- Delivery Temp: 70 °F
- Slump = 6”± 1.5”

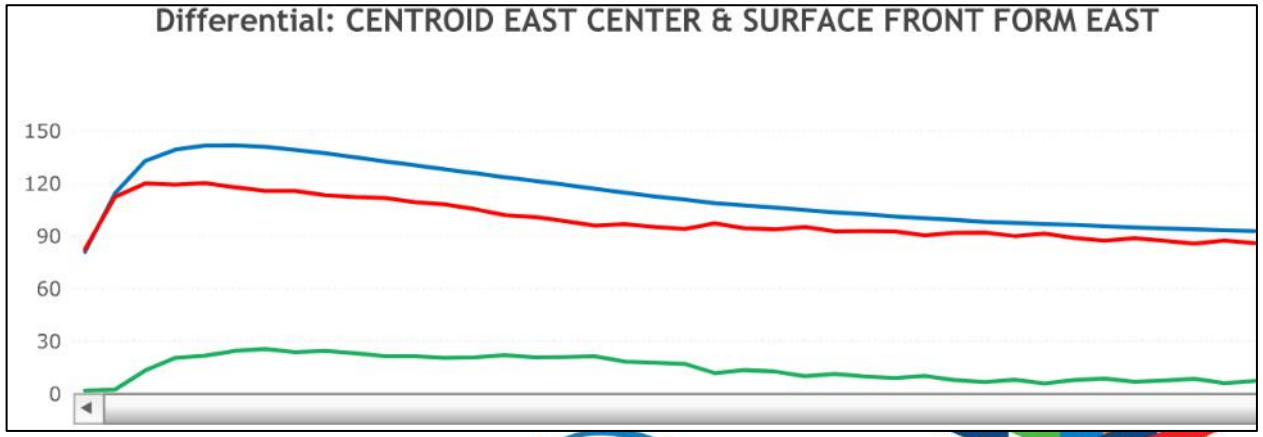
# LANDSLIDE REPAIR PR-10 FROM KM. 41.6 TO 41.9, UTUADO, PR

# LANDSLIDE REPAIR PR-10 FROM KM. 41.6 TO 41.9, UTUADO, PR

# LANDSLIDE REPAIR PR-10 FROM KM. 41.6 TO 41.9, UTUADO, PR

| Location | Maximum Temperature | Date/Time | Maximum Temperature Differential | Date/Time |
|---|---|---|---|---|
| SURFACE WEST LATERAL FORM | 127 °F | 5/17/24 at 1:27 PM | 16 °F | 5/17/24 at 6:57 PM |
| CENTROID WEST LATERAL FORM | 110 °F | 5/17/24 at 1:27 PM | 16 °F | 5/17/24 at 6:57 PM |
| SURFACE WEST | 128 °F | 5/17/24 at 5:49 PM | 20 °F | 5/19/24 at 7:17 AM |
| CENTROID CENTER WEST | 142 °F | 5/17/24 at 10:14 PM | 20 °F | 5/19/24 at 7:17 AM |
| SURFACE TOP EAST | 120 °F | 5/17/24 at 5:26 PM | 25 °F | 5/18/24 at 7:49 AM |
| CENTROID CENTER EAST | 142 °F | 5/17/24 at 9:51 PM | 25 °F | 5/18/24 at 7:49 AM |
| SURFACE FRONT FORM EAST | 120 °F | 5/10/24 at 5:13 PM | 27 °F | 5/18/24 at 7:52 AM |
| CENTROID CENTER EAST | 141 °F | 5/10/24 at 10:27 PM | 27 °F | 5/18/24 at 7:52 AM |



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# Thank you for your attention


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