MICHIGAN CONCRETE ASSOCIATION

# Concrete Quality Control Problems: How to Address Before, During, and After the Placement

PRESENTED BY THE MICHIGAN CONCRETE ASSOCIATION:

David Cook – Assistant Director of Training and Certification

# Concrete Quality Control Problems: How to Address Before, During, and After

- Welcome & Introduction

  David Cook – Assistant Director of Training and Certification

  Over 20 years experience in quality control and materials testing for commercial, industrial, and residential projects. Federal, State, and local projects.

- Before the Concrete is Placed:

  The concrete quality control plan and the pre-placement meeting.

- During the Concrete Placement:

  Site preparations, start-up, communication, issues and on-the-fly corrections.

- After the Concrete Placement:

  Curing, special testing, open-to-use, strength testing, and how to deal with failing results.

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Quality Control Plan

A Good QC plan can help prevent problems and help address problems before they happen.

Who is developing the plan? The contractor, a QC consultant, the owner's rep?

Which leads to The Organization Chart.

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Quality Control Plan

If there is a problem, make sure the QC plan addresses who and how it is reported

Chain of Command for Reporting:

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Quality Control Plan

Make sure the QC plan addresses what is and isn't a problem ahead of time.

Include a section usually titled Corrective Action Plan. The Corrective Action Plan should address:

- Stockpile Management
  - Onsite Management or Supplier Management (Uniformity Req)
- Mixing Time and Transportation
  - What Specification Governs (DOT, IBC, Project Engineer)
- Hot and Cold Weather Concreting
  - When do these kick-in? (ACI spec, DOT, Project Engineer)
- Action and Suspension Limits for Air Content and Slump
  - Include Tables or Referenced Documents or Specifications
- Time Limits for Temperature
  - Include Tables or Referenced Documents or Specifications

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Quality Control Plan – Example Action/Suspension Chart

**QC Action and Suspension Limits**

| Quality Characteristic | Action Limits | Suspension Limits |
|---|---|---|
| Air Content (percent) | ≤ 5.5 and ≥ 8.5 | < 5.0 or > 9.0 |
| Air Content Loss (percent) | 1.5 | Greater than 1.5 |
| Conc. Temp. (Deg. F) | < 50 or > 85 | < 45 or > 90 at time of placement |
| Slump (max.) (inch) | ≥ 2.75” (≥ 5.75” with MR) | Grade P1, PNC, & M: 3” Max.<br>Grade P1, PNC, & S2: 6” Max. with MR<br>(Per Approved Mix Design) |

# Concrete Quality Control Problems: How to Address Before, During, and After

Table 1001-1 (formerly 601-1) – Time between Charging Mixer and Placing Concrete

- Lower temperature limit changed from 60°F to 65°F, effectively giving producers more time to haul/discharge in slightly warmer conditions

| Type of Unit | Concrete Temperature (ASTM C 1064) | | |
|---|---|---|---|
| | <65°F | 65 to 85°F | >85°F |
| Open Top Trucks | 60 | 45 | 30 |
| Open Top Agitating Units | 60 | 60 | 30 |
| Closed Top Agitating Units and Truck Mixers | 90 | 60 | 45 |
| Truck Mixers and Closed Top Agitating Units with Water-Reducing Retarding Admixture | 120 | 90 | 70 |
| All times shown are in minutes. | | | |

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting

Another important place to prevent problems and know how to address them when they do happen; is at the pre-pour meeting. Have the discussions between all the parties involved and when things go wrong, everyone will know what to do, and who's responsible for correcting it.

Who needs to be there? And have a formal meeting where everyone is invited.

Project Manager, Superintendent, Concrete Contractor, Owner's Representative or QA consultant, QC Manager or QC Consultant, Producer's Representative

Review the QC plan and the QA plan. Make sure the plans are in accordance with project specifications and contract documents.

Review how testing is happening in accordance with the plans. In most cases the QC testing should make sure the concrete contractor is providing a consistent quality product. And the QA testing is verifying that the concrete product meets the project specifications or pay item requirements.

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting

Other important items to discuss:

Site placement preparations

- Formwork
- Reinforcing steel
- Base course
- Special placement considerations

  i.e. pump truck, tremie tube, buggies, embedded items, water stops and drainage, safety considerations.

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting

Other important items to discuss:

Are all the mix designs appropriate and approved?

-Correct W/C ratio

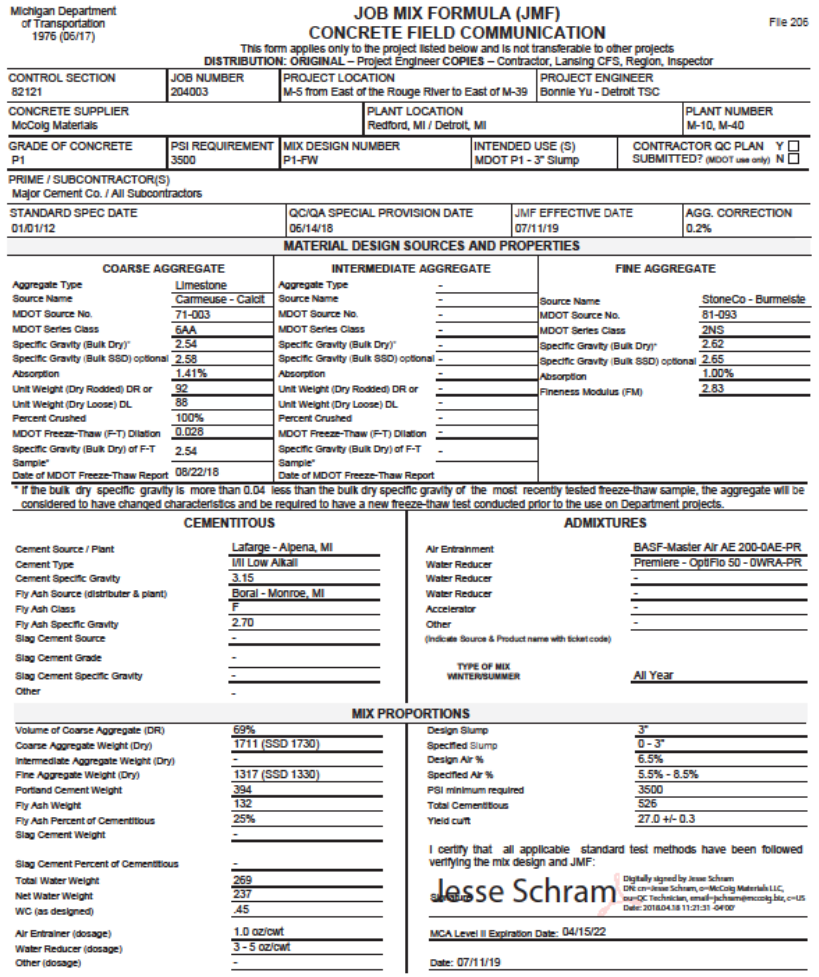
-Minimum cement requirements met

-Hot weather mix

-Cold weather mix

-Pumpability

-Gradation uniformity requirements



Michigan Department of Transportation 1976 (06/17)

**JOB MIX FORMULA (JMF)**
**CONCRETE FIELD COMMUNICATION**

File 206

This form applies only to the project listed below and is not transferable to other projects
**DISTRIBUTION: ORIGINAL** – Project Engineer **COPIES** – Contractor, Lansing CFS, Region, Inspector

| CONTROL SECTION | JOB NUMBER | PROJECT LOCATION | PROJECT ENGINEER |
|---|---|---|---|
| 82121 | 204003 | M-5 from East of the Rouge River to East of M-39 | Bonnie Yu - Detroit TSC |

| CONCRETE SUPPLIER | PLANT LOCATION | PLANT NUMBER |
|---|---|---|
| McCoig Materials | Redford, MI / Detroit, MI | M-10, M-40 |

| GRADE OF CONCRETE | PSI REQUIREMENT | MIX DESIGN NUMBER | INTENDED USE (S) | CONTRACTOR QC PLAN SUBMITTED? (MDOT use only) |
|---|---|---|---|---|
| P1 | 3500 | P1-FW | MDOT P1 - 3" Slump | Y ☐ N ☐ |

PRIME / SUBCONTRACTOR(S)
Major Cement Co. / All Subcontractors

| STANDARD SPEC DATE | QC/QA SPECIAL PROVISION DATE | JMF EFFECTIVE DATE | AGG. CORRECTION |
|---|---|---|---|
| 01/01/12 | 06/14/18 | 07/11/19 | 0.2% |

**MATERIAL DESIGN SOURCES AND PROPERTIES**

| COARSE AGGREGATE | | INTERMEDIATE AGGREGATE | | FINE AGGREGATE | |
|---|---|---|---|---|---|
| Aggregate Type | Limestone | Aggregate Type | - | | |
| Source Name | Carmeuse - Calcit | Source Name | - | Source Name | StoneCo - Burmeiste |
| MDOT Source No. | 71-003 | MDOT Source No. | - | MDOT Source No. | 81-093 |
| MDOT Series Class | 6AA | MDOT Series Class | - | MDOT Series Class | 2NS |
| Specific Gravity (Bulk Dry)* | 2.54 | Specific Gravity (Bulk Dry)* | - | Specific Gravity (Bulk Dry)* | 2.62 |
| Specific Gravity (Bulk SSD) optional | 2.58 | Specific Gravity (Bulk SSD) optional | - | Specific Gravity (Bulk SSD) optional | 2.65 |
| Absorption | 1.41% | Absorption | - | Absorption | 1.00% |
| Unit Weight (Dry Rodded) DR or | 92 | Unit Weight (Dry Rodded) DR or | - | Fineness Modulus (FM) | 2.83 |
| Unit Weight (Dry Loose) DL | 88 | Unit Weight (Dry Loose) DL | - | | |
| Percent Crushed | 100% | Percent Crushed | - | | |
| MDOT Freeze-Thaw (F-T) Dilation | 0.026 | MDOT Freeze-Thaw (F-T) Dilation | - | | |
| Specific Gravity (Bulk Dry) of F-T Sample* | 2.54 | Specific Gravity (Bulk Dry) of F-T Sample* | - | | |
| Date of MDOT Freeze-Thaw Report | 08/22/18 | Date of MDOT Freeze-Thaw Report | | | |

* If the bulk dry specific gravity is more than 0.04 less than the bulk dry specific gravity of the most recently tested freeze-thaw sample, the aggregate will be considered to have changed characteristics and be required to have a new freeze-thaw test conducted prior to the use on Department projects.

| CEMENTITOUS | | ADMIXTURES | |
|---|---|---|---|
| Cement Source / Plant | Lafarge - Alpena, MI | Air Entrainment | BASF-Master Air AE 200-0AE-PR |
| Cement Type | I/II Low Alkali | Water Reducer | Premiere - OptiFlo 50 - 0WRA-PR |
| Cement Specific Gravity | 3.15 | Water Reducer | - |
| Fly Ash Source (distributer & plant) | Boral - Monroe, MI | Water Reducer | - |
| Fly Ash Class | F | Accelerator | - |
| Fly Ash Specific Gravity | 2.70 | Other | - |
| Slag Cement Source | - | (Indicate Source & Product name with ticket code) | |
| Slag Cement Grade | - | | |
| Slag Cement Specific Gravity | - | TYPE OF MIX WINTER/SUMMER | All Year |
| Other | - | | |

**MIX PROPORTIONS**

| | | | |
|---|---|---|---|
| Volume of Coarse Aggregate (DR) | 69% | Design Slump | 3" |
| Coarse Aggregate Weight (Dry) | 1711 (SSD 1730) | Specified Slump | 0 - 3" |
| Intermediate Aggregate Weight (Dry) | - | Design Air % | 6.5% |
| Fine Aggregate Weight (Dry) | 1317 (SSD 1330) | Specified Air % | 5.5% - 8.5% |
| Portland Cement Weight | 394 | PSI minimum required | 3500 |
| Fly Ash Weight | 132 | Total Cementitious | 526 |
| Fly Ash Percent of Cementitious | 25% | Yield cu/ft | 27.0 +/- 0.3 |
| Slag Cement Weight | - | | |
| Slag Cement Percent of Cementitious | - | | |
| Total Water Weight | 269 | | |
| Net Water Weight | 237 | | |
| WC (as designed) | .45 | | |
| Air Entrainer (dosage) | 1.0 oz/cwt | | |
| Water Reducer (dosage) | 3 - 5 oz/cwt | | |
| Other (dosage) | - | | |

I certify that all applicable standard test methods have been followed verifying the mix design and JMF:

Signature: Jesse Schram Digitally signed by Jesse Schram DN: cn=Jesse Schram, o=McCoig Materials LLC, ou=QC Technician, email=jschram@mccoig.biz, c=US Date: 2018.04.18 11:21:31 -04'00'

MCA Level II Expiration Date: 04/15/22

Date: 07/11/19

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting

Other important items to discuss:

Who handles ordering and scheduling of equipment, materials, and testing?

Superintendent? Concrete contractor? Sub-contractor foreman?

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting

Other important items to discuss:

Is there a jointing plan?

Are there any floor flatness requirements?

What is the plan to achieve FF/FL numbers?

Rideability requirements?

Paver considerations, Elevation points, GPS

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting

Other important items to discuss:

How are we going to cure? Curing compounds, wet coverings, fogging, nothing?

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting

Other important items to discuss:

Hot or cold weather conditions, and how to address them.

-Change or additional approval of mix design with supplemental cementitious materials quantities adjusted.

-Time of day for placement adjusted

-Protection from elements

-Check ACI 305 (Hot) or ACI 306 (Cold) for more info

# Concrete Quality Control Problems: How to Address Before, During, and After

Before the Concrete is Placed: The Pre-Pour Meeting
Other important items to discuss:

How will contractor provide or assist in procuring samples for testing?

Testing frequency – Slump, Air, Temp, Density, Strength Specimens

Who is responsible for rejection of materials?

How and when are reports forwarded and to whom?

Where are we storing specimens?

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement:

Site Preparation

- Aggregate base, form work, and reinforcing steel in place and inspected or tested.
- Access to the placement area for trucks or a pump truck.
- Can the placement area handle the loads?
- Where are the trucks washing out after empty?
- Where is testing going to take place, and where and what type of curing facilities are being used for concrete strength test specimens.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement:

Start Up

- QC and QA start up tests and correlation – make sure you know the tolerances. Run the full round of tests- particularly if you need to be compliant with ASTM C94. Slump, Air Content, Temperature, AND Density (Unit Weight).

- Next- Start up test results are communicated to the contractor and supplier

- Do we need additional start up tests? Tests before and after the pump truck or paver machine? Make sure the QC is maintaining the tolerances.

- Does the ready-mix producer need to adjust the mix based on start up tests? It's important the producer knows how to adjust the mix at the site. The producer QC tests may have been fine at the plant, let's make sure the same concrete is delivered to the site.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement: A minute about sampling for testing…

Preliminary Sampling- Checking for air, slump, and temperature at the beginning of the load is permissible and a good way to see if the concrete is within tolerances.

- Allow about ¼ of a cubic yard to be offloaded first (A wheelbarrow or so).
- Then take a sample and perform tests.
- Inform the contractor and supplier of the results; and continue work.
- Do not mold strength test specimens from preliminary tests

Per ASTM C31 and ASTM C94 concrete strength test specimens need to be sampled in accordance with ASTM C172. Which means they need to come from a composite sample from the middle of the load; and have slump, air, temp, (and density C94) performed while molding the samples.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement:

Communication-

During the concrete placement the QC technician needs to communicate test results to the contractors (concrete foreman, ready-mix producer or RMP QC personnel and the site superintendent, and the QA person or owner's representative). And all parties need to communicate with one another and decide if any changes during placement need to happen.

If QA tests indicate issues, the QA technician needs to communicate results to the QC personnel; and the QC need to implement any action or suspension limits requirements that are laid out in the QC plan.

Open communication during placement is essential to provide a quality product. Don't wait till the pour is over to tell anyone we had an issue. Or worse yet, wait till the report is sent out days later showing there were out of specification test results.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement: Issues and on-the-fly corrections

How do we know we have a problem? Check the action/suspension limits!

**QC Action and Suspension Limits**

| Quality Characteristic | Action Limits | Suspension Limits |
|---|---|---|
| Air Content (percent) | ≤ 5.5 and ≥ 8.5 | < 5.0 or > 9.0 |
| Air Content Loss (percent) | 1.5 | Greater than 1.5 |
| Conc. Temp. (Deg. F) | < 50 or > 85 | < 45 or > 90 at time of placement |
| Slump (max.) (inch) | ≥ 2.75" (≥ 5.75" with MR) | Grade P1, PNC, & M: 3" Max.<br>Grade P1, PNC, & S2: 6" Max. with MR<br>(Per Approved Mix Design) |

If we are in the ranges for action limits, let everyone know the results. Then check the QC and follow its directions. The work can continue, but everyone needs to know we may need to slightly change things.

If we are in suspension limits, it's time to stop the pour. If an instant resolution can't be found. It may be time to reject the truck; and make greater changes to the concrete or placement methods.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement: Issues and on-the-fly corrections

**Example of action limits planned response**

When test results deviate from specified ranges, immediate action will be taken to return results to acceptable levels. If the test results exceed action limits, the next available truck will be tested. If the test results from the second truck meet acceptable levels, no additional testing will be required. However, if the second truck tested also exceeds action or suspension limits, production will be suspended. The truck can be corrected onsite if the limits are out of specification on the low end (example: Air content is low- admixture is added to truck and remixed and retested). If the limits are out of specification of the high side, the concrete is rejected.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement: Issues and on-the-fly corrections

**Example of suspension limits planned response**

If QC suspension limits are exceeded, QC personnel will notify the Contractor and Engineer/Engineer's Representative and the batch plant will be instructed to stop production and adjust the mix to bring it within tolerance. Trucks with measured slump or temperature exceeding maximum specification limits (Suspension Limits) will be rejected immediately and placement will not be allowed, regardless of the total mixing time at arrival to the project. Once two successful tests meet production limits, concrete placement can resume.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement: QC and QA strength specimens

Compressive strength cylinders

- QC cylinders made for information purposes.
- Usually made at regular intervals during the placement.
- May include early test date specimens- 3 day, 7 day, 28 day.
- May include both field cure and regular cured specimens
  If field cured- make sure they are treated the same as the concrete placed.
- QA cylinders made for acceptance purposes. Random intervals.
- Typically only 28 day strength tests for approval of payment or acceptance of compliance with the project requirements.
- Make sure all standard cured specimens are kept between 60-80F and some sort of monitoring system records the temperature. Min/Max thermometers, or maturity meters, or cure box with integrated temperature communication devices.

# Concrete Quality Control Problems: How to Address Before, During, and After

During the concrete placement: QC and QA strength specimens

Flexural Strength Beams

- QC beams made for information purposes. Or to allow the pavement to open to traffic.
- Can be made at regular intervals, or at the end of the day on the last load.
- May include early test date specimens- 1 day, 3 day, 7 day, 28 day.
- Typically going to be field cured.
- QA beams made for acceptance purposes. Usually random intervals.
- Typically only 28 day strength tests for approval of payment or acceptance of compliance with the project requirements.
- Check your project requirements. DOT projects treat beams far differently then a FAA project.

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: Curing

The most important and often over-looked part of quality concrete! Make sure to plan ahead.
Thinking about curing after you already started pouring often results in under achieving finished product.

- Curing compounds
- Spraying, flooding, or misting
- Burlap with/or plastic coverings
- Curing cylinders
- Protection in hot or cold conditions

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: Special Testing

- Floor Flatness/ Floor Levelness Testing
  When are we doing FF/FL?
- Vapor Emissions
  Calcium Chloride Test Kits
  Relative Humidity Probes
- Rideability
- Thickness Coring

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: Open to Use

- Removal of forms/backfilling operations- Compressive strength 70%
- Removal of cold protection- differential heat change and danger of cracks
- Allow light traffic/continued construction- Compressive strength 75%
  Or also consider this equation:

$$= \frac{\text{Dead load + construction load}}{\text{Total design load}} \times \text{grade of concrete}$$

- Open to traffic or allow paving operations to cross the slab
  Flexural strength beams – Some conditions allow 300psi. DOT typically 550psi for open to traffic. Check your project specifications!
- Maturity Meters – Make sure you have correlating data. Upload and know what it means. Communicate via RFDI, wifi, or cellular networks.

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: Strength testing results (ASTM C94)

For a strength test, at least 2 standard test specimens shall be cast from a composite sample.

A test is defined as the average of the strengths obtained at the age specified – Typically 28 days. If a specimen shows evidence of improper sampling, molding, handling, curing or testing it shall be discarded and the strength of the remaining cylinder considered the test result.

Additional tests may be made at other ages to obtain information for determining form removal time or when a structure may be put into service.

Specimens for such tests are field cured as compared to standard cured.

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: Strength testing results (ASTM C94)

The Running Average of Three!!!

The average of any three consecutive strength tests shall be equal to, or greater than, the specified strength, f ‘$_c$ and…

When the specified strength is 5000 psi or less, no individual strength test shall be more than 500 psi below the specified strength, f ‘$_c$ or…

When the specified strength is greater than 5000 psi, no individual strength test shall be less than 0.90 f '$_c$

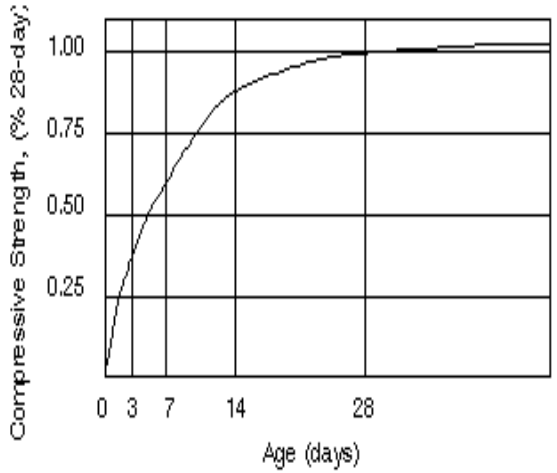



Figure 1. Typical strength-gain curve.

# Concrete Quality Control Problems: How to Address Before, During, and After

$f'_c$ = 4000 psi **The Running Average of Three Example**

| **Day 1** | **Test (psi)** | |
|---|---|---|
| 7:30 am | 4500 | avg. of 2 cylinders (minimum) |
| 9:00 am | 4200 | |
| 1:00 pm | 3900 | Part A - Ave. 3 consecutive = 4200 psi, ok |
| | | Part B - No strength below 3500 psi ,ok |
| **Day 2** | | |
| 10:00 am | 3600 | Part A - Ave. 3 consecutive = 3900 psi, not ok |
| | | Part B - No strength below 3500 psi, ok |

**Overall: Does not pass – Day 2 results**

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: How to deal with failing results

Non-destructive confirmation of results- Rebound Hammer

- Generally only going to be used to get more information.
  Not to be used in a dispute resolution.
  Affected by surface types and different finishes.

- Must have correlating data from other rebound tests of companion cylinders of the same mix to create a strength comparison chart.

- Need to do tests on in-place “Good” concrete and correlate to tests of in-place “Bad” concrete

- Probably best used to find the limits of the “Bad” concrete

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: How to deal with failing results

Semi-Non-destructive confirmation of results- Windsor Probe

- Generally only going to be used to get more information. Not to be used in a dispute resolution except for rare cases. Leaves a small hole in the concrete that may not be desired.
- Must have correlating data from other Windsor probe tests of companion cylinders of the same mix to create a strength comparison chart.
- Need to do tests on in-place “Good” concrete and correlate to tests of in-place “Bad” concrete.
- Probably best used to find the limits of the “Bad” concrete.

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: How to deal with failing results

Destructive confirmation of results- Coring (ASTM C42)

- The most commonly used method to confirm test results. Leaves a large hole and may damage surrounding area. Take a minimum of 3 cores and average results.

- Testing must be done in strict accordance with the standard to be representative of the structure being tested. Must be kept moist during transportation. And stored in a cure facility the appropriate amount of time before strength tested.

- Due to the violent nature of obtaining the core; the strength tests of the cores is considered adequate if they meet 85% of F'c, and no individual core is less than 75% of F'c.

# Concrete Quality Control Problems: How to Address Before, During, and After

After the concrete placement: How to deal with failing results

- Strict Remove and Replace?
- Repair? Contractor warranties future performance.
- Payment Deduction?
- Meet with all parties involved and have discussions about what needs to be done.
  Can the engineer back off of F'c; If the results are only slightly low? The required overdesign may have been enough to make up for the underperforming concrete? Or do contract documents require strict specification enforcement?

# Concrete Quality Control Problems: How to Address Before, During, and After

**CONCLUSIONS:**

- Before the placement we develop great QC/QA plans and make sure everyone knows what is in it. And have a good pre-placement meeting with all parties involved to discuss the pour; Then we can head off QC problems before they happen.
- During the placement we need proper trained testing people with calibrated testing equipment we will get good test results. If we have problems, we follow the plan to resolve them.
- After the placement, we use good curing techniques, do all the follow up testing in accordance with specifications, and make sure to get the reports out promptly; we will have a great finished product. And if any problems do arise, make sure to communicate with all parties and resolve the problems in a prompt manner.

MICHIGAN CONCRETE ASSOCIATION

# QUESTIONS?

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