

ALDOT-170-82
METHOD OF CONTROLLING CONCRETE OPERATIONS
FOR PORTLAND CEMENT CONCRETE

1. Scope

This procedure establishes compliance requirements for control of the concrete operations on concrete structures and concrete pavements. These requirements are set forth by the Alabama Department of Transportation, herein referred to as ALDOT or as the Department.

2. Related/Referenced Documents

2.1. ALDOT Standard Specifications for Highway Construction (Web link: [ALDOT SPECIFICATIONS](#)):

- Section 260 Cement Mortar Flowable Backfill
- Section 450 Portland Cement Concrete Pavement
- Section 501 Structural Portland Cement Concrete
- Section 504 Steel Pile Encasements
- Section 506 Drilled Shafts
- Section 512 Precast Non-Prestressed Concrete Bridge Members
- Section 513 Prestressed Concrete Bridge Members
- Section 571 Shotcrete
- Section 801 Coarse Aggregate
- Section 802 Fine Aggregates
- Section 806 Mineral Admixtures
- Section 807 Water
- Section 808 Air Entraining Additives
- Section 809 Chemical Admixtures for Concrete
- Section 815 Cement

2.2. ALDOT Procedures (Web link: [ALDOT PROCEDURES](#)):

- ALDOT-175 Method for Stockpiling Coarse Aggregate for All Purposes
- ALDOT-352 Qualification Program for Portland Cement Concrete Producers
- ALDOT-355 General Information Concerning Materials, Sources, and Devices with Special Acceptance Requirements
- ALDOT-364 Procedure for Acceptance of Precast Concrete Products to Include Concrete Pipe, Precast Manholes, Precast Box Culverts and Miscellaneous Precast Products

- ALDOT-367 Production and Inspection of Precast Non-Prestressed and Prestressed Concrete
- ALDOT-405 Certification and Qualification Program for Concrete Technicians and Concrete Laboratories
- ALDOT-407 Calibration Verification of Truck Mounted Water Meters.

2.3. BMT Forms:

- BMT-10 Notice Stamp for Acceptance (Aggregates)
- BMT-75 Concrete Mixture Design
- BMT-83 Concrete Placing Daily Report
- BMT-95 Concrete Plant Checklist
- BMT-122 Concrete Batch Ticket

2.4. ALDOT Approved Sources:

- MSDSAR Materials, Sources and Devices with Special Acceptance Requirements manual. (Web link: [MSDSAR](#))

2.5. AASHTO Standards:

- T 22 Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens
- T 24 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- T 152 Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method
- T 160 Standard Method of Test for Length Change of Hardened Hydraulic Cement Mortar & Concrete
- T 255 Standard Method of Test for Total Evaporable Moisture Content of Aggregate by Drying
- T 277 Standard Method of Test for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
- M 157 Standard Specification for Ready-Mixed Concrete

2.6. ASTM Standards:

- C 192/C 192M Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory.
- C 457 Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete.
- C 642 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete.
- C 823 Standard Practice for Examination and Sampling of Hardened Concrete in Constructions.
- C 856 Standard Practice for Petrographic Examination of Hardened Concrete.

2.7. ACI Standard:

- 211.1 Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete.
- 214R-02 Evaluation of Strength Test Results of Concrete

3. **Materials**

Materials shall meet the requirements in Division 800 of the Department's Specifications and shall be from approved sources as listed in the Department's MSDSAR manual. Specific reference is made to the following specifications and approved lists:

- Section 801, Section 802, and List I-1 – Coarse Aggregate and Fine Aggregate
- Section 815 and List I-2 – Cement
- Section 806 and List I-3 – Mineral Admixtures
- Section 808, Section 809, and List II-1 – Chemical Admixtures
- Section 807 - Water

4. **Mixture Design**

- 4.1. The concrete producer shall establish the proportion of materials for each class of concrete in the form of a one cubic yard {cubic meter} concrete mixture design. Specific concrete mixture design criteria can be found in Sections 450, 501, 504, 506, 512 and 513 of the Department's Standard Specifications.
- 4.2. The concrete producer shall provide a concrete mix design with 28-day compressive strength verification using the concrete materials required in Sections 260, 504, 506, and 571.

- 4.3. The proposed concrete mixture shall be designed by means of developing a three-point curve of laboratory trial batches for Sections 450, 501, 512, and 513. Three-point curves shall be developed and tested as follows:
 - 4.3.1. Mixture proportions shall be selected on the basis of laboratory trial batches using at least three different water-cementitious ratios that will produce a range of strength encompassing the 28-day Target Compressive Strength (f'_{cr}) required for each class of concrete.
 - 4.3.2. Trial batches shall be made using the exact materials the concrete producer intends to use during actual production. Trial batches shall be made following the methodology described in the American Concrete Institute procedure ACI 211.1.
 - 4.3.3. The Target Compressive Strength used to select mixture proportions with a required minimum 28-day compressive strength (f'_c) shall be determined using the following equations:
 - 4.3.3.1. For f'_c less than 3000 psi {21 MPa}
$$f'_{cr} = f'_c + 1000 \text{ psi } \{7 \text{ MPa}\}$$
 - 4.3.3.2. For f'_c from 3000 to 5000 psi {21 to 35 MPa}
$$f'_{cr} = f'_c + 1200 \text{ psi } \{8.5 \text{ MPa}\}$$
 - 4.3.3.3. For f'_c greater than 5000 psi {35 MPa}
$$f'_{cr} = f'_c + 1400 \text{ psi } \{10 \text{ MPa}\}$$
 - 4.3.4. For each water-cementitious ratio, at least three 6" x 12" cylinders for each test age shall be made and cured in accordance with ASTM C 192/C 192M. Cylinders shall be tested at 7 and 28 days in accordance with AASHTO T 22.
 - 4.3.5. The slump, total air content, and temperature of the concrete for each trial batch shall be reported.
 - 4.3.6. Concrete producers shall determine the design target value for slump and total air content for all trial batches. All trial batches shall produce a total air content falling within the specified range and shall not exceed the maximum specified slump, including the allowable field tolerance.
 - 4.3.7. For concrete mixture designs including Type "F" chemical admixtures to receive the specified slump allowance, slump values shall be reported before and after the addition of the Type "F" chemical admixture.
 - 4.3.8. Trial batches used to design mixtures, as applicable for Section 501, shall be tested for permeability in accordance with AASHTO T 277 and/or drying shrinkage in accordance with AASHTO T 160.
 - 4.3.9. For each trial batch, a curve shall be plotted showing the relationship between water-cementitious ratio and strength, and the relationship between 7-day and 28-day strengths.
- 4.4. Separate three-point curves shall be developed for each combination of cementitious materials. Separate three-point curves shall also be developed for any proposed concrete

with conveying or placing methods requiring special properties or to be placed in unusual placing locations.

- 4.5. Any change to an approved concrete mixture design must be requested by the contractor in writing and approved in writing by the Materials and Tests Engineer. Changes in aggregate source, mineral admixture source, chemical admixture, cement type, or proportions of the materials shall require a new concrete mixture design.
- 4.6. Developing and testing of three-point curves shall be performed by certified concrete technicians, as required by the Department. Three-point curves shall be developed and tested at ALDOT qualified concrete laboratories conforming to the requirements of ALDOT - 405.

5. Submittal of Concrete Mixture Design

- 5.1. The concrete producer shall submit to the Materials and Tests Engineer a letter requesting approval of the proposed concrete mixture design. This letter shall be accompanied by the proposed concrete mixture design, test results, supporting data, and any other pertaining information. The concrete producer shall allow the Department 28 Calendar Days to complete the review and approval of the proposed concrete mixture design.
- 5.2. The following minimum supporting data and information shall be required prior to approval of any mixture design:
 - 5.2.1. The source and type of each material proposed, including vendor codes.
 - 5.2.2. The individual gradation of each aggregate, the combined gradation of the total blended aggregates, the aggregate correction factor (determined in accordance with AASHTO T 152), the fineness modulus of fine aggregate, and the saturated-surface-dry (SSD) specific gravity and absorption of all aggregates.
 - 5.2.3. The Class of the proposed concrete mixture and the proportions for one cubic yard {cubic meter}.
 - 5.2.4. Freshly mixed concrete properties. This shall include actual results for slump, total air content, and temperature of the concrete for each trial batch.
 - 5.2.5. Evaluation of compressive strength test results showing the Target Compressive Strength.
 - 5.2.6. Laboratory trial batches, three point curves, and target values used to design trial batches.
- 5.3. Three-point curves containing trial batches that were tested more than one (1) year prior to the date of submittal will not be accepted for approval.
- 5.4. A laboratory Quality Control Manager or a Technical Service Manager authorized by the qualified laboratory developing the proposed mixture design, or a professional Engineer, licensed in the State of Alabama and not employed by ALDOT, shall sign all test results

and supporting data submitted to the Department. Unsigned submittals shall be returned to the originator.

5.4.5.5. For all mix designs to be used in the production of precast, prestressed bridge members, elastic modulus values must be provided.

6. Approved Concrete Mixture Design Distribution

- 6.1. Upon approval, the Bureau of Materials and Tests will provide the concrete producer with a BMT-75 form containing the approved concrete mixture design(s) from which the concrete producer shall choose to use in supplying concrete to Department projects.
- 6.2. Unless otherwise specified, the BMT-75 shall be valid for a period of four years. However, it can only be used if the concrete producer maintains its National Ready Mix Concrete Association (NRMCA) certification status. No changes or modifications are allowed to be made to an approved BMT-75 form.
- 6.3. Prior to using an approved concrete mixture design on a specific project, the Contractor shall submit each proposed BMT-75 to the respective Division Materials Engineer, along with the project number and a detailed description of the structure(s) where the concrete mixture will be used. This request shall be submitted a minimum of seven (7) calendar days prior to use of the concrete mixture design.
- 6.4. Prior to granting approval to use an approved mixture design on a specific project, the Division Materials Engineer will review the information on BMT-75 and verify that the concrete mixture design(s) submitted meets the requirements for the project contract. The Division Materials Engineer will also verify that the concrete producer has a current NRMCA certification.
- 6.5. The Division Materials Engineer, upon approval, will notify the Contractor. If the concrete mixture design submitted does not meet the requirements for the specific project, the Division Materials Engineer will notify the Contractor of the reason(s) for non-approval.
- 6.6. Upon approval, the Division Materials Engineer will submit copies of the BMT-75, with the specific project number, structure name, and compliance with NRMCA noted, to the Materials and Tests Engineer, Contractor and Concrete Producer.
- 6.7. The Division Materials Engineer may approve the use of a back-up plant on any project, provided the back-up plant has an approved concrete mix design and the materials used by each plant are the same. Back-up plants will only be allowed when technical difficulties hinder the primary plant from providing concrete to the job site within the Department specifications. When the use of a back-up plant is allowed, the Project Manager will maintain records of exact placement locations for further reference. **Two different concrete plants cannot supply concrete to the same structure, on a given project, unless requested by the contractor in writing and approved in writing by the Materials and Tests Engineer prior to placement.**

- 6.8. Copies of approved BMT-75 forms shall be kept in the project file at the concrete producer's plant at all times.

7. Re-Approval of Concrete Mixture Design

- 7.1. A concrete mixture that has performed satisfactorily in the field throughout its approved period may be submitted by the concrete producer for re-approval consideration to the Materials & Tests Engineer.
- 7.2. The concrete producer shall request re-approval of the concrete mixture design at least 30 calendar days prior to its expiration date.
- 7.3. The following minimum data and information shall be submitted by the concrete producer with the re-approval request:
- 7.3.1. Original data submitted for original concrete mixture design approval.
- 7.3.2. Statistical analysis of data collected from concurrent placements since the time the concrete mixture design was originally approved.
- 7.3.3. The statistical analysis shall meet all the following minimum requirements:
- Control charts of individual strengths, slumps, temperature, and total air content test results.
 - Control charts showing the moving average for individual compressive strength, slump, temperature, and total air content test results. The moving average shall be based on the previous five tests.
 - Documentation related to the concrete compressive strength shall be submitted for the 7 and 28 day test specimens. Note that for the purpose of compressive strength, a test shall be defined as the average of the compressive strengths of two cylinders made from the same sample of concrete and tested at the same age.
 - Statistical analysis shall be performed on data collected from a minimum of 30 consecutive tests.
 - Separate sets of test data shall be submitted for each Class of concrete mixture design to be re-approved. All submitted data shall include the date the actual tests were conducted.
 - The following formulas shall be used in deriving the average, standard deviation, and coefficient of variation.

$$\begin{aligned}x_i &= \text{Value of an individual test} \\n &= \text{Total number of tests} \\ \bar{x} &= \text{Mean value of all tests } (x_i) \text{ as calculated from:}\end{aligned}$$

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

s = Standard deviation of the test results as calculated from:

$$s = \sqrt{\frac{n \sum_{i=1}^n x_i^2 - \left(\sum_{i=1}^n x_i\right)^2}{n(n-1)}}$$

C_v = The coefficient of variation as calculated from:

$$C_v = \left(\frac{s}{\bar{x}}\right)100$$

7.3.4. Any additional information relevant to the performance of the concrete mixture.

7.4. The average compressive strength of all data submitted for review shall meet or exceed the minimum required average strength, computed using the following equation (derived from ACI 214R-02):

$$f'_{cr} = f'_c + 1.96s$$

where f'_c = specified strength

and

s = standard deviation of sample population

7.5. Re-approval of the concrete mixture design will be at the sole discretion of the Materials and Tests Engineer.

8. Concrete Plants, Concrete Equipment, and Concrete Materials

8.1. All equipment, tools, and machinery necessary for forming, mixing, placing, finishing, and curing concrete shall be in satisfactory working condition before the Contractor will be allowed to place concrete on Department projects. The Department reserves the right to inspect this equipment at any time to insure its workability.

8.2. Concrete plants shall meet the requirements of Sections 450 and 501 and ALDOT-352

8.3. Moisture probes shall be calibrated every six months in accordance with ALDOT-352.

8.4. Concrete transit mixers shall be equipped with an approved water metering device and an automatic counter meeting the requirements of Section 501.

8.5. The Department will conduct concrete plant inspections in accordance with ALDOT-352.

- 8.6. All materials used in the production of concrete for Department projects shall meet the requirements of ALDOT-352 for handling and storing materials.

9. Control of Mixing Operations

- 9.1. The Producer's ALDOT certified Concrete Technician shall follow the approved BMT-75 in regard to the desired proportions of each ingredient that enters into the mixture.
- 9.2. The Producer's ALDOT certified Concrete Technician shall check that all materials used in the production of concrete are from Department approved sources.
- 9.3. The Producer's ALDOT certified Concrete Technician shall be responsible for testing and making aggregate moisture adjustments.
- 9.4. Additional requirements for the control of concrete mixing operations, including on the job mixing, are found in the following documents:
- Sections 450, 501, 504, 506, 512 and 513
 - ALDOT-352
 - ALDOT-364
 - ALDOT-367
 - AASHTO M 157
- 9.5. The Producer's ALDOT certified Concrete Technician shall check the temperature of the portland cement and mineral admixtures prior to and during production. Cement shall not be used if its temperature is greater than 150 °F {65 °C}. The temperature readings shall be recorded in the Concrete Plant Diary.
- 9.6. The Producer's ALDOT certified Concrete Technician shall test at the concrete plant for slump, temperature, and total air content, each day of production after the first load of concrete is batched and every 100 cubic yards {75 cubic meters} or fraction thereof for each class of concrete produced for the Department. The test results shall be recorded on a BMT-122 and in the Concrete Plant Diary.
- 9.7. The concrete producer shall maintain, at the plant and readily available to the Department for review, a Quality Control Plan in accordance with ALDOT-352

10. Records and Reports

- 10.1. The Project Manager will keep records and reports of all concrete operations in the project. The records and reports will be used to determine compliance with the contract

specifications, to control concrete operations, and to ensure timely action in taking corrective steps to avoid substandard quality concrete.

- 10.2. The Producer's ALDOT certified Concrete Technician shall keep records of all plant concrete operations in the Concrete Plant Diary, including conversations with the Project Manager, other ALDOT personnel, other individuals, and any calculations in relation to concrete produced for the Department.
- 10.3. The concrete producer shall keep on file the following minimum references, records, and reports. Some of these documents may be accessed from the Department's website at www.dot.state.al.us
 - Copy of ALDOT Standard Specifications for Highway Construction.
 - Copy of Alabama Department of Transportation Testing Manual.
 - Copy of the Materials, Sources, and Devices with Special Acceptance Requirements manual.
 - Copy of all applicable AASHTO & ASTM Specifications
 - BMT - 75
 - BMT - 10
 - BMT - 83
 - BMT - 122
 - Test reports for all compressive strength tests
 - Concrete Plant Diary with records of moisture corrections and aggregate gradations
 - Copy of NRMCA Certification
 - Control charts for total air content, slump, temperature, and strength for each Class of concrete mixture

11. Procedure for Forensic Investigations

- 11.1. The testing laboratory will notify the Division Materials Engineer when the compressive strength of the specimens tested is below the specified compressive strength.
- 11.2. The Division Materials Engineer will conduct an investigation on the substandard concrete to determine the cause. The results of the investigation and recommendation will be reported to the Materials and Tests Engineer.
- 11.3. The Materials and Tests Engineer will forward the Division's findings and recommendations and any additional recommendation to the Construction Engineer for final handling.

- 11.4. The Division Materials Engineer may request the assistance of the Bureau of Materials and Tests to perform forensic investigations that are outside the Division's capabilities. This request must be in writing (letter, fax, or e-mail), addressed to the Materials and Tests Engineer and clearly stating the problem and requested assistance..
- 11.5. Upon receiving the forensic investigation request, the Bureau of Materials and Tests will determine if an investigation is necessary, which may include coring and/or petrographic analyses, to determine the cause(s) of the problem.
- 11.6. For structural components that are not accessible or too small for coring, the Department may use other methods to determine the acceptability of the concrete. A core investigation will be conducted by the Bureau of Materials and Tests, or its consultant, as follows:
 - 11.6.1. Delineate the area on the structure with substandard concrete as represented by the set of concrete cylinders with low compressive strength.
 - 11.6.2. The rebound hammer instrument will be used to select a location for coring within the affected area of the structure.
 - 11.6.3. The procedure for the use of the rebound hammer is as follows:
 - For linear members the length of the member affected will be divided into ten equal segments or three foot {one meter} long segments if the affected length is greater than thirty feet {ten meters}.
 - For area members the area of the member affected will be divided into sixteen equal segments or nine square foot {one square meter} segments if the affected area is greater than 150 square feet {fifteen square meters}.
 - Three rebound hammer readings will be taken in each segment and averaged. The segment with the lowest average readings will be the location for coring.
 - 11.6.4. Three cores will be obtained, cured, and tested within 42 days from concrete placement. One set of three cores will be obtained for every set of low compressive strength cylinders. Cores will be obtained within 35 days after placement of the concrete to allow for the required curing and testing to be completed within the above required 42 days. The Materials and Tests Engineer shall approve any deviation from this schedule in writing.
 - 11.6.5. Personnel from the Bureau of Materials and Tests shall extract the cores. If personnel from the Bureau of Materials and Tests are not available, a laboratory qualified by the Department, as per ALDOT-405, shall be used by the Contractor to extract the cores. Cores shall be obtained as per AASHTO T 24 and immediately protected and shipped to the Bureau of Materials and Tests with all pertinent information. If a qualified laboratory is used to extract the cores, an ALDOT representative will be present during all coring operations.
 - 11.6.6. Extreme caution will be taken to ensure that no reinforcing steel or prestressed strands are cut during the coring operation.
 - 11.6.7. Core specimens will be measured, cured, and tested in accordance with AASHTO T

24. Proper strength correction factor will be applied to cores having a length-to-diameter (L/D) ratio less than two.

- 11.7. If required, the Bureau of Materials and Tests, or its consultant, will conduct a petrographic investigation. The specimens for petrographic analyses will be obtained at the same time that core specimens are obtained.
- 11.8. The core investigation and/or petrographic investigation will be used to determine the acceptability or rejection of substandard concrete.
- 11.9. The Department reserves the right to use other types of investigation as necessary to fully determine the cause(s) for substandard concrete, and use them to determine the acceptability or rejection of the questionable concrete.
- 11.10. The Materials and Tests Engineer will forward investigation findings and recommendations to the Construction Engineer and copy the Bridge Engineer and Division Engineer.

12. Repair of Core Drilled Holes

- 12.1. All accepted members shall have cores holes repaired using the same concrete mixture design used to originally cast the members.
- 12.2. The following procedure outlines the minimum requirements to repair core drilled holes:
 - Mixing of concrete shall be completed a minimum of 45 minutes prior to placing.
 - The concrete mixture shall be re-mixed without adding any water just before placing.
 - The area to be repaired shall be prepared by scarifying and roughening the concrete surface.
 - Apply an approved Type II or Type V Epoxy in accordance with the epoxy manufacturer's recommendations.
 - The re-mixed concrete shall be packed in place with small tools and consolidated by tamping.
 - The repair shall be cured for seven days using wet curing or approved membrane-curing compounds. For repairs on bridge decks, only wet curing shall be allowed.
 - After curing, the repaired area shall be finished so as to provide a uniform appearance with the adjacent concrete.
- 12.3. Other repair methods may be used if requested in writing to, and approved by, the Materials and Tests Engineer. Alternate repair procedures shall not be used until approved by the Materials and Tests Engineer.