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Contractor Quality Control For Structural Cast-in-Place Concrete

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EXECUTIVE SUMMARY

This report outlines the specific requirements for a proposed quality control (QC) program for cast-in-place (CIP) structural concrete to be implemented through pilot projects administered by the California Department of Transportation (Caltrans). The intent of this proposal is to place adequate responsibility and accountability on contractors for QC of structural concrete materials. This endeavor was initiated as a result of a Caltrans Management Decision Document signed in December 2010 which provided direction to shift responsibility for QC of structural concrete materials away from Caltrans and to the contractor. Quality Assurance in the form of Independent Assurance and Acceptance Testing will continue to be performed by Caltrans, the details of which are documented in a separate report (Quality Assurance Guidelines for Structural Concrete). The delivery plan for this overall goal was completed in January 2011 (Figure 1) and it was determined that liaison with industry groups would be achieved through the already established Concrete Materials and Quality Assurance (QA) subtask group of the Rock Products Committee.[1]

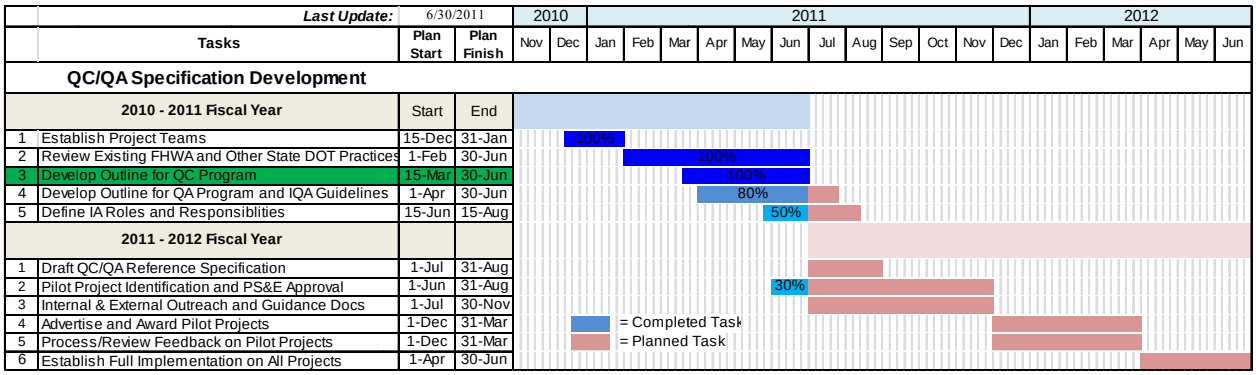

Figure 1 - Summary of Tasks from Delivery Plan Developed in Response to Approved Decision Document

As the first step, under the subtask group a project team was developed representing various relevant functional groups of Caltrans along with representative industry members. As the second step, a comprehensive review of Federal Highway Administration (FHWA) requirements and other state Departments Of Transportation (DOT) practices was conducted and documented in a separate report (See *Review of State Highway Agency Quality Assurance Program* report). This report represents the third step in the overall delivery plan developed in response to the decision document. Bi-weekly meetings were held for a period of four months with project team members to achieve consensus on various QC program requirements to be incorporated into the Caltrans specifications.

This report documents the specific QC elements that will need to be changed, modified, or added to the specifications to reflect the new QC program requirements. For each element, the decision-making process has been documented in an effort to provide general guidance to the authors of the specifications. It is envisioned that implementation will begin with pilot projects in FY 11-12. The specific elements of the QC program requirements are summarized in Appendix-1. The summary documents the consensus reached with all stake holders. The report establishes requirements for test methods, inspection practices, construction methods, materials handling practices, certification/accreditation, and dispute resolution, and identifies specific areas to be monitored during pilot projects so that final specifications can be created after incorporating lessons learned. Some of the items were reviewed in creating the summary report and achieving consensus include:

- FHWA guidelines regarding state-of-the-art QC/QA practices and practices of other DOTs;
- Lessons learned from other QC/QA specifications of Caltrans (e.g. Section 40 Pavement and 8-2 Precast);
- Typical industry practices and other national standards.

[1] The Rock Products Committee (RPC) is a cooperative effort of Caltrans, industry associations, and the Federal Highway Administration. The RPC provides a forum for Caltrans and industry representatives to coordinate joint efforts aimed at improving construction methods, material specifications, and test methods utilized in the construction and preservation of transportation facilities. The Concrete Task Group and Concrete Materials and QA Subtask group deals with issues related to concrete materials and products on behalf of the Rock Products Committee.

KEY ISSUES

Below is the brief summary of key issues in development of this program. Each of these items is discussed in greater detail in the body of the report.

Contractor's Quality Control Program and Accreditation

An important component of a QC/QA program is the contractor's QC plan. The Project team concluded that a QC plan that enumerates the quality characteristic to be measured during production will be necessary in the new QC program requirements. The team agreed on the characteristics that, if properly controlled during production, would be accurate indicators of the quality of the end product. Measuring these characteristics is dependent on the quality and reliability of the personnel and facilities performing the tests. As such, the project team recommends that, in order to provide increased confidence and reliability in the test results, personnel, plant and laboratories are certified and/or accredited to the following appropriate certifications:

- American Concrete Institute (ACI) certifications for field and Lab personnel
- AASHTO Accreditation for Laboratories
- National Ready Mix Concrete Association (NRMCA) for concrete facilities

Through the discussions of the project team, another variable affecting the overall quality of structural concrete was the lack of an overall system or process to manage approved mix designs. The Project Team recommends that mix designs be prequalified and a database of prequalified mix designs be developed and maintained by Caltrans. As part of the mix design review, test results for aggregate source material will be submitted by the contractor. These will include test results for the specific gravity and absorption of aggregates, durability index, abrasion (LA rattler), soundness, and organic impurities in fine aggregate. Once verified (and provided there is no change to the source or the test results are not too old), the material will be listed as "prequalified" and suitable for use in the mix with no retesting required.

Testing Methods and Frequencies

Through the process, a detailed comparison of California Test Methods (CTM) and American Society for Testing and Materials (ASTM) test methods was made for concrete materials (including aggregates). The STG reached consensus that nationally recognized ASTM standards should be used for all material tests associated with the QC/QA pilot projects. Frequencies for testing are listed in the table in Appendix-1 and are also discussed in the body of this report. They do not represent a major departure from frequencies currently specified by Caltrans. QA testing (guidance discussed in a separate report) is then performed at a lower frequency level by Caltrans in line with FHWA expectations.

Dispute Resolution Process

The dispute resolution process was discussed at length among the project team members and members of the STG. It is the consensus of the project team that the dispute resolution processes follow requirements in Section 90 with respect to current operating and compliance ranges for materials. This will allow for a simplified implementation during the pilot projects. Based on lessons learned from the pilot program, a more comprehensive dispute process will be potentially developed and recommended by the team. An incentive/disincentive program will be considered and evaluated after the pilot program that utilizes both the contractor's and Caltrans test results (An edited version of Section 90 is included in this report in the dispute resolution section). This provides the contractor with contract compliance expectations. It was the consensus of the team that additional guidance regarding QA testing frequency and dispute resolution scenarios will be provided in forthcoming documents.

INTRODUCTION

This report documents concurrence received by the project team and represents final product of the team which was constituted by various stake holders. This report will provide guideline to specification writers to understand reasoning behind various elements of this program. To develop an efficient and effective contractor QC program, a thorough review of other states departments of transportation (DOT) practices, industry practices, and existing national standards was undertaken. These items included (but were not limited to) FHWA regulations and guidance documents, state DOT standard specifications, industry practices, documents from NRMCA, ASTM, and ACI. This research provided an understanding of quality control practices developed around the country.

The contractor quality control specifications, when developed, will be evaluated on a series of selected pilot projects throughout the State of California. Initially, the proposed specifications will apply to structural concrete projects. This will allow for the refinement of the specifications for structural concrete. A separate QC/QA program is envisioned for paving concrete. Also, the quality control specifications will be written in the format recommended by the "2010 Style Guide" in order to be consistent with the new 2010 Plain Language specifications.

QUALITY CONTROL PLAN

According to the proposed specifications, the contractor is required to submit a QC plan that clearly defines all the necessary actions required in the quality control effort. This plan was developed in a similar manner to that already used in the inspection of structural steel and precast concrete. The plan is to include the following items:

- Quality Control Manager
- Qualified Personnel including Laboratory and Field Technicians
- Independent Testing Facilities
- Mixing Plant Certifications
- Mix Design Qualifications
- Quality Control Procedures

Quality Control Manager

The Quality Control Manager (QCM) is required to be employed by the contractor or with quality control firm and must possess at least one of the following certifications/registrations: ACI Lab Technician Grade I; professional engineer registration in the State of California; NICET certification; ICC Reinforced Concrete certification or an equivalent certification. The requirement for certification was added to underscore the importance of the responsibilities of the QCM. Having a QCM professionally responsible for the accuracy of the reports he/she is submitting to Caltrans provides an added level of assurance. The QCM is responsible for all QC functions and for ensuring all materials adhere to the contract requirements. The QCM is also responsible for reviewing and all documents, including the Quality Control Plan, prior to submitting to Caltrans and may be augmented by field inspection staff to provide overall quality control of the product. Lessons learned related to Quality Control procedures and manager from welding and precast section will be added during specification development.

Qualified Personnel including Laboratory and Field Technicians

The QC plan is also required to include information about the qualified personnel such as their names and certifications. The QC testing personnel are required to have ACI Laboratory Technician Level I or equivalent certifications. Field Testing and inspection personnel are required to have ACI Field Technician Level or equivalent

certifications. Test methods required to achieve these certifications are included in the Appendix 3. These requirements are industry standards and many other state DOT QC/QA specifications include similar requirements.

INDEPENDENT TESTING FACILITIES

The specifications for testing facilities include the possession of current American Society of State Highway Transportation Officials (AASHTO) accreditation. Currently, the laboratories that perform testing for Caltrans are certified by Caltrans for each CTM. Since the proposed QC requirements specify ASTM test methods instead of CTMs, there was a need for participation in the AASHTO accreditation program to assure that the laboratories have the ability to comply with ASTM test standards. For laboratories, AASHTO is the only accrediting body approved by the FHWA (Appendix 4). Many other state DOTs also require laboratories to hold current AASHTO accreditation. This change in the specification will be beneficial to the industry as they no longer need to go through multiple certifying agencies, specifically the laboratories that perform material testing for both FHWA and U.S. Army Corp of Engineers projects.

MIXING PLANT REQUIREMENTS

The STG undertook an in-depth review of the Portland Cement Concrete (PCC) batch plant certification process. Currently, Caltrans uses the California Test 109 (CT 109) – Method for Testing of Material Production Plants in accordance with the Material Plant Quality Program (MPQP) developed in July 2008. The goal of this review was to determine how CT 109 compared with current national standards as well as certification programs used by other DOTs and if any changes to the current Caltrans policies are necessary.

The primary national standards that govern the certification of PCC batch plants are ASTM C94, AASHTO M157, and the NRMCA Certification of Ready Mixed Concrete Facilities. Several state DOTs have developed independent programs similar in scope to California's while others have adopted the NRMCA program to verify that the batch plants supplying material to their projects conform to a referenced specification. The U.S. Army Corp of Engineers has also adopted NRMCA.

CT 109 is a general procedure for testing and approving weighing and measuring devices. These devices include hopper scales, liquid volumetric metering devices, conveyor scales, and volumetric proportioning plants. Certification of these devices occurs once per year or whenever the equipment is repaired or moved. The test method also includes plant safety requirements. CT 109 does not include a certification for delivery vehicles which are especially important for dry-mix plants. All CT 109 testing is performed by trained state personnel. Section 1B is a general requirement that the entire plant be inspected to ensure that all parts comply with the contract documents. However, the document does not go into specifics on how the inspection should proceed.

ASTM C94 *Standard Specification for Ready-mixed Concrete* is an all-encompassing national specification covering ready mixed concrete. *Section 10: Batching Plant, Section 11: Mixers and agitators, Section 12: Mixing and Delivery, and Section 15: Plant Inspection* are the applicable sections. These sections outline the minimum requirements that a plant and its delivery fleet, must fulfill to provide quality concrete to a customer. However, it does not provide a certification to a plant; it is merely a guideline. AASHTO M157 *Standard Specification for Ready-mixed Concrete* is nearly identical to ASTM C94 in intent and scope.

The NRMCA Certification of Ready Mixed Concrete Facilities is a national program developed to:

> "…provide a system for establishing that production equipment and procedures at ready mixed plants are satisfactory." – *NRMCA Plant Inspector's Guide May 2011*

Currently there are 1800 concrete plants nationwide holding this certification, with 194 plants certified in California alone and certification can be received in couple of weeks once plant is ready for it at a reasonable cost. Several states have adopted the NRMCA as their primary plant certification program. These states include Michigan, South Carolina, Texas, Washington, Alabama and others. The ACI also recommends invoking the NRMCA certification program by inclusion in the project specifications.

The program was developed to provide a means to verify that plant meet or exceed the requirements of ASTM C94, AASHTO M157, the Truck Mixers Manufacturers Bureau, and the Concrete Plant Standards of the Concrete Plant Manufacturers Association. The inspection of plants is performed by a licensed professional engineer who has been approved by NRMCA and holds valid registration in the state in which the plant is located. The NRMCA Certification of Ready Mixed Concrete Facilities covers materials storage and handling, batching equipment, central mixers, the ticketing system, and delivery fleet inspection. Inspection of each of these items is explained in detail in the *NRMCA Plant Inspector's Guide,* which the inspecting engineer is required to obtain and follow. Certification of production facilities is valid for two years from the date of inspection. Certification of the delivery fleet is good for 14 months.

The NRMCA program encompasses all of the facets of CT 109 while also including provisions for the certification of the delivery fleet. CT 109 does not include the delivery fleet. The certification of the plant by a professional engineer and the commitment to quality that is required of the certified plant's executive has led the STG to recommend the adoption of the NRMCA Plant Certification Program by the Caltrans. To provide a smooth transition and to verify that the NRMCA procedures correspond with CT109/MPQP, it is recommended that CT109/MPQP be maintained along with the NRMCA certification for the purpose of pilot programs. This item will be evaluated closely at the end of pilot program prior to finalizing the Standard Special Provisions (SSP).

MIX DESIGN QUALIFICATIONS

Every concrete mix design will be required to be qualified. Once the mix receives the approval for a specific use by Caltrans, the mix provided by that supplier may be used on multiple projects for the same use provided it remains unaltered. If any part of the mix changes (i.e. aggregate source, cement source or type, etc.), the mix will be required to be re-qualified. A database of prequalified mix designs will be maintained by Caltrans. Each approved mix design will be tracked and stored by its unique combination of identification numbers.

The test results listed in Table 1 must be submitted with the mix design. The acceptance criteria will remain unchanged from existing specifications. These tests will only be required during the mix design phase as they are intended to verify the properties of the aggregates supplied. The results should be within one year of submission of mix design to accurately represent condition of the source. Once verified, as long as there is no change to the source, they will be good for use in the mix with no retesting required.

Specific Gravity and Absorption of Aggregates	ASTM C127 & C128
Durability Index	ASTM D3744
LA Rattler	ASTM C131
Soundness	ASTM C88 (Use Sodium Sulfate)
Organic Impurities in fine fraction	ASTM C40 & C87

Table 1 – Test Results to Be Submitted with Mix Designs

Use of a fine aggregate failing in the test of Organic Impurities in Fine Fraction (ASTM C40) is not prohibited, provided that, when tested for the effect of organic impurities on strength of mortar, the relative strength at seven days, calculated in accordance with ASTM C87, is not less than 95 percent.

QUALITY CONTROL PROCEDURES

Part of the STG review efforts focused on reviewing standard specifications and QC procedures of other states. The review revealed that many states have adopted ACI standards as part of their quality control procedure due to the fact that ACI standards are nationally recognized by other organizations. As a result of this finding, ACI standards (found to be equivalent to CTMs) were reviewed and a comparison was performed. ACI standards are also in accordance with AASHTO specifications. The following procedure outline was generated in accordance to *ACI 311 Quality Control, SP-2(07)* and standard industry practices*:*

i. Contractor will perform all sampling and testing required to produce concrete in accordance with the contract documents and approved quality control plan.
ii. Sampling shall be in accordance with ASTM C 172.
iii. After concrete has been delivered and incorporated in the project, the contractor shall submit copies of all QC tests performed, stamped by a professional engineer registered in the State of California.
iv. The contractor should provide the inspection and related QC testing of the batching and mixing operations at the concrete batch plant.
v. The quality control effort, at minimum, would include the following activities:
    1. Verify proper storage of all materials on a daily basis during concrete operations.
    2. Observe at least the first batch to ensure that the correct mix is being produced and the fine moisture corrections are being applied to the aggregates.
    3. Verify that the cement and other sources of cementitious material are from the approved source (check haul trucks for correct load ticket).
    4. Verify that the scales and other measurement systems have been properly calibrated within the specified time frame.
    5. Verify that the plant and truck mixers have been qualified in accordance with the NRMCA checklist for the ready-mix concrete production facilities. Check mixer trucks for excessive mixer blade wear and proper operation of the revolution counters, and verify the condition of the water tank and date of calibration.
    6. Check to determine if the batch plant has the ability to spray aggregates and if the plant is capable of maintaining the concrete consistency during periods of extreme heat and low temperature ranges.
    7. Check admixture dispensers to determine they are able to deliver the correct dosages within the accuracy requirement specified in the project specifications.
    8. Assure that the moisture content is within half a percent of aggregate moisture. (NRMCA certification)
    9. Check initial delivery ticket; note if ticket shows hold back mix water and is signed by the weigh master. Verify that the concrete as batched confirms to the approved concrete mix design weights.
    10. Visually inspect all concrete during placement operations.

TESTING METHODS AND FREQUENCIES

After examining the testing methods for aggregate and concrete of each state, a table of the equivalency of CTM and comparable ASTM was generated (Appendix 6). Each ASTM was selected to fulfill the same purpose as the CTM. It was concluded that ASTM specifications are more likely to keep a uniform and standard procedure intact. Although not all CTMs were fully replaced by ASTM standards based on analysis of all the test methods equivalent tests are found where the intent is satisfied. The following table indicates the proposed test methods along with their minimum frequencies. Frequencies were determined by the ACI and standard industry practices and cross referenced against Construction Manual guidance. Test results should be approved and stamped by a licensed professional engineer from the supplier or the laboratory, or by the QC manager. Once the testing is complete, the results should be electronically submitted to Caltrans per the instructions provided in the contract documents.

Test	Test Method	Minimum Frequency
Aggregate Gradation	ASTM C136	Once a day
Sand Equivalent	ASTM D2419	Once a day
% fines under 75 micron (Coarse Agg Only)	ASTM C117	Once a day
Moisture Content (within half a percent of specified moisture)	ASTM C566	1-2 times daily depending on conditions (at batch plant)
Slump	ASTM 143	First truckload delivered and once every 100CY or when consistency is in question
Unit Weight	ASTM 138	During mix design or when grading has changed or once every 30 CY when air is specified, whichever is higher
Air Content	ASTM 173 / ASTM C231	Once every 30 CY when air is specified
Temperature	ASTM C1064	Once every 100 CY or one day of pour
Compressive Strength	ASTM C31/C39	Once every 100 CY or one day of pour

Table 2 - Testing Methods and Frequencies

ASTM C136 is a variation of AASHTO T27. Since the sampling procedure of C136 is very similar to CTM 202 (with minor differences), it is acceptable to consider the two tests equivalent to one another and propose ASTM C136 as the aggregate gradation test method.

Sand equivalent testing provides a measure of the relative proportions of detrimental fine dust or clay. This method is tested on a portion of the aggregate that is smaller than 4.75 mm in size. ASTM 2419 fulfills the same purpose of CTM 217; hence they are considered equivalent.

CTM 227 is currently being used as a test for evaluating the cleanness of coarse aggregate that determines the percentage of fines to assure good bonding between particles. ASTM C117 is a measure of the extremely fine

particles and is achieving the same (if not more accurate) results as CTM 227. ASTM C33 (Appendix 8) provides the acceptable limits for coarse aggregates as 1 percent by weight, and 1.5 percent if the aggregate does not contain clay or shale. A larger value is allowed to be calculated per footnote C of Table 3 of ASTM C33 (Appendix 8). This is used if it is known that the fine aggregate contains less than the maximum allowed by ASTM C33. The STG recommends that the operating range be taken as 1.5 percent and contract compliance is 2 percent.

For the concrete slump test, ASTM 143 is specifically considered for slump and it is proposed to consider the ASTM method over the CTM to continue the uniform system of using ASTM standards.

ASTM C138 is considered to be suitable for the unit weight test during mix design or when grading has changed and to replace CTM 513.

Since ASTM C231 and CTM 504 are essentially equivalent test pressures and methods, they can be completely substituted.

PCC temperature is currently tested by CTM 557 is based on ASTM C1064. CTM 557 and ASTM C1064 have very similar language and can be considered equivalent.

Concrete compressive strength is currently being tested by CTM 521 for molded concrete cylinders. This test method is actually a modification of ASTM C39 and AASHTO T 22. ASTM C39 has a tighter rate of loading with a maximum rate less than CTM and minimum rate higher than CTM. Although the verbiage and details of the tests differ by some degree, they are still considered equivalent and substitutable. The size of the cylinder and capping method will be addressed during specification update.

Language will be added in the specification to put QCM responsible for quality of concrete delivered, where with help of technician or other staff, he is able to accept or reject concrete delivered prior to Caltrans making their assessment.

DISPUTE RESOLUTION PROCESS

To comply with the FHWA requirements, the Project team addressed the need for a Dispute Resolutions System. A Dispute Resolutions System is required if the results from the QC sampling and testing are used in the QA acceptance program. Dispute resolution processes of several other DOTs were reviewed as noted in Appendix 7. The process was discussed at length among the project team members and members of the STG during several meetings. It was agreed that since Caltrans currently does not have enough database of testing, a statistical based dispute process may not be suitable and may unnecessarily complicate the specification in depicting each possible scenario. It is the consensus of the project team that the dispute resolution processes follow requirements in Section 90 with respect to current operating and compliance ranges for materials for aggregates and 95% and 85% strength levels for compressive strength.

This will allow for a simplified implementation during the pilot projects. Based on lessons learned from the pilot program, a more comprehensive dispute process will be potentially developed and recommended by the team. An incentive/disincentive program will be considered and evaluated after the pilot program that utilizes both the contractor's and Caltrans test results. This provides the contractor with contract compliance expectations. It was the consensus of the team that additional guidance regarding QA testing frequency and dispute resolution scenarios will be provided in forthcoming documents.

To minimize the changes, the corresponding sections of 2010 specifications are modified to accurately capture the proposed approach. This will be further reviewed and finalized by specification writers. Additional guidance will be provided through Caltrans internal guidance documents and bulletins for dealing with various scenarios and

acceptable variations between inter laboratory results and standard deviations established by ASTM methods. A draft modification to Section 90-1.01D(5) Compressive Strength is included in the Appendix 9 , and shows how variations in results could be addressed through pre-established 95% and 85% allowance based on additional testing including coring.

For aggregates corresponding sections of 90-1.02C Aggregates is modified to appropriately handle disputes as noted in Appendix 10 as a proposal. Operating range and contract compliance is used to allow for inherent variations associated with test methods and sampling. Non-conformance method and evaluation of test data will be used as measure to assure that these important parameters of Sand Equivalent, % fine in coarse aggregate and gradation is tightly controlled.

In addition, here ASTM equivalent of Cleanliness Value (CV) is used. The acceptance range is based on what is recommended in ASTM C33 and currently used in other industry standards. It was also noted through discussion that % fines in coarse aggregate (CV) is rarely seen out of compliance by district staff.

CONCLUSION

This outline has been produced to provide a set of guidelines to the authors to allow development of a revision to the non-standard special provision (nSSP) for structural concrete intended for implementation on selected pilot projects. The use of contractor QC in the acceptance process of concrete material has been approved by the FHWA for use, and has increased in use by state agencies. With a well thought out and detailed plan, Caltrans can successfully implement these procedures and better allocate its resources across all of its structural concrete projects.

APPENDICES

Appendix 1: *Outline and Concurrences for Quality Control Procedures for Structural Concrete*

<table>
<tr><td>

Quality Control Plan (Quality Control Manual)
Contractor shall submit a quality control plan that clearly defines all Items listed A thru E

A. Quality Control Manager
vi. Requirements & Responsibilities
1. Employed by Contractor or sub-contractor who is doing QC functions
2. Responsible for all QC functions
3. Shall perform review of all documents including Quality Control Manual and procedures prior to submittal to the State
4. Responsible to ensure all materials adhere to the contract requirements
5. ACI lab grade level I or PE or NICET certification or ICC reinforced concrete certification or equivalent

</td><td>Concurrence received 6/28/11</td></tr>
<tr><td>

B. Qualified Personnel
vii. Requirements
1. Names of all QC testing Personnel
a. ACI Laboratory Technician Level I or equivalent*
2. Names of all Field Personnel
a. ACI Field Technician Level I or equivalent

</td><td>Concurrence received 4/8/11</td></tr>
<tr><td>

C. Independent Testing Facilities
viii. Requirements
1. Laboratory must possess current AASHTO accreditation

</td><td>Concurrence received 4/28/11</td></tr>
<tr><td>

D. Mixing Plant Certifications
ix. Ready mix plant must possess current CT109/MPQP and NRMCA Certification*

</td><td>Concurrence received 5/26/11</td></tr>
<tr><td>

E. Mix design qualifications
Unique identification for each mix
All structural concrete will require prequalification
All the necessary tests and following tests only required in qualification stage

<table>
<tr><td>Specific Gravity of Aggregates</td><td>ASTM C127 & C128</td></tr>
<tr><td>Durability Index</td><td>ASTM D3744</td></tr>
<tr><td>LA Rattler</td><td>ASTM C131</td></tr>
<tr><td>Soundness</td><td>ASTM C88 (Use Sodium Sulfate)</td></tr>
<tr><td>Organic Impurities in fine fraction</td><td>ASTM C40</td></tr>
</table>

These test to be monitored eventually on prequalification basis

</td><td>Concurrence received 6/28/11</td></tr>
<tr><td>

II. QC Procedures
i. Contractor will perform all inspection, sampling and testing required to produce concrete in accordance with the contract documents and approved Quality Control Plan.

</td><td>Concurrence received 6/28/11</td></tr>
</table>

ii. Sampling shall be in accordance with ASTM C 172 iii. After concrete has been delivered and incorporated in the project, the contractor shall submit copies of all Quality Control tests performed, stamped by a Professional Engineer registered in the State of California. iv. The contractor should provide the inspection and related Quality Control testing of the batching and mixing operations at the concrete batch plan. v. The quality control effort, at minimum, would include the following activities: 1. Verify proper storage of all materials on a daily basis during concrete operations. 2. Observe at least the first batch to ensure that the correct mix is being produced and the moisture corrections are being applied to the aggregates. 3. Verify that the cement and other sources of cementitious material are from the approved source (check haul trucks for correct load ticket). 4. Verify that the scales and other measurement systems have been properly calibrated within the specified time frame. 5. Verify that the plant and truck mixers have been qualified in accordance with the NRMCA checklist for the ready-mix concrete production facilities. Check mixer trucks for excessive mixer blade wear, proper operation of the revolution counters and verify the condition of the water tank and date of calibration. 6. Check to determine if the batch plant has the ability to spray aggregates, and if the plant is capable of maintaining the concrete consistency during periods of extreme heat and low temperature ranges. 7. Check admixture dispensers to determine that they are able to deliver the correct dosages within the accuracy requirement specified in the project specifications. 8. Assure that the moisture content is within half a percent of aggregate moisture. (NRMCA certification) 9. Check initial delivery ticket, note if ticket shows hold back mix water, and is signed by the weigh master. Verify that the concrete as batched confirms to the approved concrete mix design weights. 10. Visually inspect all concrete during place operations.	

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vi. The following testing will be required at the frequencies listed in the table below:

<table>
<tr><th>Test</th><th>Test Method</th><th>Minimum Frequency</th></tr>
<tr><td>Aggregate Gradation*</td><td>ASTM C136</td><td>Once a day</td></tr>
<tr><td>Sand Equivalent*</td><td>ASTM D2419</td><td>Once a day</td></tr>
<tr><td>Percent fines under 75 micron (Coarse Aggregate Only)*</td><td>ASTM C117</td><td>Once a day</td></tr>
<tr><td>Moisture Content (within half a percent of specified moisture)</td><td>ASTM C566</td><td>1-2 times daily depending on conditions (at batch plant)</td></tr>
<tr><td>Slump</td><td>ASTM 143</td><td>First truckload delivered and once every 100CY or when consistency is in question</td></tr>
<tr><td>Unit Weight</td><td>ASTM 138</td><td>During mix design or when grading has changed or once every 30 CY when air is specified, whichever is higher</td></tr>
<tr><td>Air Content</td><td>ASTM 173 / ASTM C231</td><td>Once every 30 CY when air is specified</td></tr>
<tr><td>Temperature</td><td>ASTM C1064</td><td>Once every 100 CY or one day of pour</td></tr>
<tr><td>Compressive Strength</td><td>ASTM C39</td><td>Once every 100 CY or one day of pour</td></tr>
</table>

All testing data to be submitted electronically to the department as per instructions listed in the Specifications
</td>
<td>Concurrence received 5/26/11</td>
</tr>
<tr>
<td>
Dispute resolution process and lot identification*
- Use current processes of step results
- Modify aggregate and compressive strength sections of concrete
</td>
<td>Concurrence received on 6/28/11. Construction expressed concerns regarding performing QA aggregate testing and using aggregate testing for acceptance, which will be discussed at TG level.</td>
</tr>
</table>

**** Based on extensive discussions during project team meetings as well as comments from STG and project team, it has been agreed that these elements will be closely monitored during pilot projects to make appropriate changes/adjustments based on lessons learned. For example augmentation of field ACI technician with ICC reinforcement concrete inspectors to perform necessary inspections during concrete placement.***

Appendix 2: ***Michigan Department of Transportation Standard Specifications***
Section 604 Contractor Quality Control

Qualifications: The quality control plan administrator must meet one or more of the following criteria: a professional engineer licensed in the State of Michigan; an individual certified by the National Institute for Certification of Engineering Technologies (NICET) at Level III or above for concrete; or an individual certified as a Concrete Technician Michigan Level II through a program certified by the Michigan Concrete Association Board of Examiners or the Michigan Concrete Paving Association.

Individual(s) performing designated tests must be certified concrete technician(s) through a program certified by the Michigan Concrete Association (Michigan Level I or II) or through the Michigan Concrete Paving Association (Level I or II-three year certification).

Furnish the name(s) and credentials of the quality control staff to the Engineer before the start of concrete sampling and testing.

Appendix 3: ***American Concrete Institute Technician Certification Program***
http://www.concrete.org/certification/cert_prog.asp

Laboratory Technician Level I

- C617 - Capping Cylindrical Concrete Specimens
- C1231 - Unbonded Caps for Concrete Cylinders
- C39 - Compressive Strength of Cylindrical Concrete Specimens
- C78 - Flexural Strength of Concrete (Using Simple Method with Third-Point Loading)
- T2 / D75 - Sampling of Aggregates
- T248 / C702 - Reducing Samples of Aggregate to Testing Size
- T11 / C117 - Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- T27 / C136 - Sieve Analysis of Fine and Coarse Aggregates
- T85 / C127 - Specific Gravity and Absorption of Coarse Aggregates
- T84 / C128 - Specific Gravity and Absorption of Fine Aggregates
- T255 / C566 - Total Evaporable Moisture Content of Aggregates by Drying
- T21 / C40 - Organic Impurities in Fine Aggregates for Concrete

Laboratory Technician Level II

- ACI 214 * - Evaluation of Strength Test Results of Concrete
- ACI 211.1 * - Selecting Proportions for Concrete
- ASTM C192/C192M - Making and Curing Concrete Test Specimens in the Laboratory (This standard also requires the knowledge and ability to perform ASTM C143 [Slump], C173 and C231 [Air Content], C138 [Unit Weight], and C1064 [Temperature].)
- ASTM C470/C470M * - Molds for Forming Concrete Test Cylinders Vertically
- ASTM C496/C496M * - Splitting Tensile Strength of Cylindrical Concrete Specimens
- ASTM C42/C42M * - Obtaining and Testing Drilled Cores and Sawed Beams

Field Technician Level I

- C1064/C1064M - Temperature of Freshly Mixed Hydraulic-Cement Concrete
- C172 - Sampling Freshly Mixed Concrete
- C143/C143M - Slump of Hydraulic-Cement Concrete
- C138/C138M - Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- C231 - Air Content of Freshly Mixed Concrete by the Pressure Method
- C173/C173M - Air Content of Freshly Mixed Concrete by the Volumetric Method
- C31/C31M - Making and Curing Concrete Test Specimens in the Field

Appendix 4: ***FHWA Question and Answers on Quality Assurance***

http://www.fhwa.dot.gov/pavement/materials/qanda637.cfm

"Who will be responsible for qualifying private laboratories that do either quality control or acceptance testing on State projects? Can qualification of private laboratories be through AMRL, A2LA, or other qualifying bodies? If the State needs to be responsible for qualifying all private laboratories, this would put a strain on their own training program.

The regulation allows the State to establish the qualification program. The only requirement is that the program must include equipment checks and that records of calibration checks must be maintained. The State can use a service for any or all parts of the qualification program as long as the minimums are met. Qualified personnel must do all testing used in the acceptance decision. All non-State IA testing and dispute resolution testing must be done by qualified personnel in an AASHTO accredited laboratory."

The Federal Register, dated June 29, 1995, indicated that, at the time, the only acceptable accreditation program was the AASHTO Accreditation Program (AAP). Since then, has any other accrediting organization been approved or applied for approval?

As indicated in a Notice in the Federal Register on September 22, 2004, the FHWA will use the National Cooperation for Laboratory Accreditation (NACLA) Accreditation Body Recognition Procedure and Technical Requirements for Construction Materials Testing, NISTIR 7012, as the criteria for the approval of comparable laboratory accreditation programs. At this time no other accreditation body has been approved. See the non-regulatory supplement for further information.
http://www.fhwa.dot.gov/legsregs/directives/fapg/0637bsup.htm

Many states choose to use modified forms of AASHTO/ASTM procedures as part of their acceptance decision. However, these procedures are not evaluated in the AAP. Is AMRL/CCRL considering revising their position on accreditation of non-standard procedures?

No. Accreditation will only be available on either the AASHTO or ASTM procedures.

Appendix 5: ***National Ready Mixed Concrete Association Plant Certification Checklist Sample***
Full checklist available at http://www.nrmca.org/research_engineering/Plant_Certification/Main.htm

QUALITY CONTROL MANUAL
SECTION
3
Eleventh Revision, May 2011

Plant Certification Check List

Certification of Ready Mixed Concrete Production Facilities

NRMCA

ENGINEER – PLEASE COMPLETE (PRINT)

☐ First Time Application

☐ Recertification Application (info from previous cert)
Plant ID # _____
Certification ID # _____

Plant Name; *Example: Plant No. 1*

Prior Plant Name if changed

Physical Street Address

Mailing Address

City, State & Zip Code of Plant

City, State & Zip Code

Plant Phone

Plant Fax

If Portable plant, Prior Address

Name of Company Operating Plant

FOR NRMCA USE ONLY

Comp ID		Eng		Date Received	
Plnt ID		Ass:		Date Checked	
Cert ID		Comp Off		Pending	
Batching	☐ M ☐ PA ☐ SA ☐ A		#Trucks	Response	
Recording	☐ CM ☐ Agg ☐ W ☐ Adm		Trucks for Cert	Inspection Date	
Mixing	☐ T ☐ C ☐ S		CW Statement ☐ Yes	Expiration Date	
Pmt Date		Check #	☐ Amex ☐ Visa ☐ MC	Auth #	
Pmt Amt	$	Inv #	Completed by:		

Notes

National Ready Mixed Concrete Association – Engineering Division
900 Spring Street, Silver Spring, Maryland 20910
Phone: (301)587-1400 Fax: (240)485-1172
Website: www.nrmca.org

1. Material Storage and Handling

1.1 Cementitious Materials

1.1.1 Bins or silos tight and provide for free movement to discharge opening. ☐

1.1.2 Where storage is provided for different types of cement or cementitious materials, different materials isolated to prevent intermingling or contamination. ☐

1.2 Aggregates

1.2.1 Procedures for unloading aggregate such as to prevent harmful segregation and breakage. ☐

1.2.2 Procedures for building stockpiles or other storage methods such as to prevent harmful segregation and breakage. ☐

1.2.3 Stockpiles or other storage located to prevent contamination; arranged to assure that each aggregate as removed from its stockpile or other storage is distinct and not intermingled with others. ☐

1.2.4 Intraplant handling and transportation such as to prevent harmful segregation. ☐

1.2.5 Separate storage bins or compartments for each size and type of aggregate properly constructed and charged to prevent mixing of different sizes or types. ☐

1.3 Water

1.3.1 Adequate supply, with pressures sufficiently constant or regulated to prevent interference with accuracy of measurement. ☐

1.3.2 For plants seeking certification to supply concrete in subfreezing weather i.e., where concrete is placed regularly during sub-freezing weather, minimum heating capacity for water and/or aggregate of 15 boiler output horsepower(BHP) per 100 cubic yard average daily cold weather production. (May be reduced to 10 BHP if storage capacity permits round-the-clock operation of heating equipment.) One BHP = 33,500 BTU per hour transferred to the water. See Note 1. ☐

Note 1. *If this requirement is not met and the facility is in an area where NOAA weather records show an average of more than 5 days per year when the minimum temperature is 32°F (0°C) or below, the Certificate of Conformance will carry the notation that the "Facility does not meet all requirements for furnishing concrete in subfreezing weather."*

1.4 Admixtures

1.4.1 For plants in areas with weather conditions as in Note 1, storage and handling system for liquid admixtures sufficiently protected to prevent freezing of admixtures at any time. (Freezing can cause ingredients of some liquid admixtures to separate and, therefore, affect concrete quality control.) See Note 2. ☐

Note 2: *Protection of admixture from freezing is required even if the plant does not produce concrete in cold weather. The inspector can accept a letter from the admixture supplier indicating that the admixtures that are being stored at the specific plant location do not need protection from freezing. Plants located in areas that do not witness freezing temperatures should be indicated to meet this provision.*

1.4.2 Admixtures protected to prevent damage from contamination. ☐

1.4.3 Agitation provided for liquid admixtures that are not stable solutions. ☐

2. Batching Equipment

Note 3: *This Check List indicates minimum requirements for verification of the accuracy of measuring devices. Records of such verifications should be reviewed by the inspector. For agencies that require NRMCA certification that have provisions for accuracy verification that are more restrictive than those stated here, those provisions would govern for the applicable plants. The requirements of this Check List govern when provisions of other agencies are less restrictive than stated here.*

2.1 Scales

2.1.1 Each scale comprised of a suitable system of levers or load cells which will weigh consistently within the tolerances given in 2.1.2, with loads indicated either by means of a beam with balance indicator, a full-reading dial, or a digital read-out or display. For all types of batching systems, manual through automatic, the batchman must be able to read the load indicating devices from his normal station. Where the controls are remotely located with respect to the batching equipment, monitors or scale-follower devices may be used if they repeat the indication of the master scale within ± 0.2 percent of scale capacity. ☐

2.1.2 Each scale accurate (Note 4) within ±0.15 percent of scale capacity or ±0.4 percent of net applied load, whichever is greater, throughout the range of use. Scale accuracy shall be verified through a combination of test weights, substitute loads, and strain loads (Note 5). Test weights used for scale accuracy should be at least 10 percent of scale capacity. Test weights should be accurate to ±0.01 percent of indicated value verified at least once every two years (Note 6). For a digital read-out from a dial scale, the tolerance shall be increased to ± 0.25 percent of capacity to allow for tracking restriction (Note 7) ☐

Note 4: *The engineer supervising inspection may accept scale calibrations made by state or other agencies if these calibrations demonstrate compliance with the requirements of 2.1 and subsections.*

Note 5: *Substitute and strain loads are defined in the NRMCA Plant Inspector's Guide and in NIST Handbook 44, 2007 edition, Section 2.20, Notes N.1*

Note 6: *Verification of scale accuracy may be made by qualified plant personnel or by outside agencies or scale calibration companies. The required accuracy of standard test weights conforms to NIST Class F defined in NIST Handbook 105-1. Scale accuracy should be verified using certified test weights to not less than 10 percent of the scale capacity, substitute loads to not less than 50 percent of scale capacity, and combination of test weights, substitue loads or strain loads in not less than each of the upper two quarters of the scale capacity up through the normal range of use.*

Note 7: *The purpose of this increased tolerance is to allow for the fact that digital readings from a potentiometer attached to a dial scale are limited to whole-number values which cannot reproduce weight indications closer than ± 0.05 percent of capacity.*

2.1.3 Company official agrees to verify accuracy of scales not less frequently than every 6 months and arrange for prompt recalibration and correction in accordance with 2.1.2 if the plant is moved or noncompliance is indicated. Signed statement by responsible official is attached. See Agreement in Section 7. Note 8. ☐

Note 8: *The purpose of the Agreement in Section 7 is to assure awareness by the operator and the company official of the necessity to verify weighing accuracy continuously.*

Appendix 6: ***Comparison of CTMs and ASTM Tests***

Aggregate Tests		
Test Type	CTM	ASTM
LA abrasion test	CTM 211- Method of test for abrasion of coarse aggregate by use of the Los Angeles rattler machine	C 131 – 06 Standard test method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine. This test method has stricter weight tolerances
Summary	No significant differences, ASTM seems to be worded a little differently and nominally more stringent in certain requirements. Therefore, ASTM C131 can satisfy all the requirements of CTM 211.	
Organic Impurities	CTM 213- Method of test for organic impurities in concrete sand	C40-Standard test method for organic impurities in fine aggregates for concrete
Summary	Minor differences in the steps and verbiage, however exactly same procedure and outcome. ASTM C 40 can satisfy all the requirements of CTM 213	
Cleanliness for Coarse Aggregates	CTM 227- Method of test for evaluating cleanness of Coarse Aggregates	No comparable ASTM however ASTM C117- Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
	Determines percentage of loose clay type particles (less than 75 micron) adhered to the coarse aggregate. Gives qualitative idea of material finer than 75 micron, might be able differentiate between presence of silt and clay and organic particles. Lengthy test procedure	Determines all the particles smaller than 75 micron from coarse or fine or combined aggregates. Gives only quantitative idea about fines (material smaller than 75 micron), no differentiation can be made in type of fines. Relatively easy test procedure, an additional step after the sieve analysis
Summary	For concrete it is important to determine percentage fines to assure good bond, which can be accomplished by both tests. Looking at the intent of the spec, either test may be ok and allowed- input needed from district laboratory.	
Relative mortar strength	CTM 515-Method of test for relative mortar strength of Portland cement concrete sand	No comparable ASTM
Summary	The test is eliminated from the standards through CPD as well as in new 2010 plain language and therefore do not need to worry about it.	
Surface moisture test	CTM 223 – Method of test for surface moisture in concrete aggregates by the displacement method (field method).	ASTM C 70 – 06 Standard test method for surface moisture in fine aggregates.
	This test covers both fine & coarse aggregates, only volumetric approach used.	Used for fine aggregates only. Sample size much smaller than CTM. Uses mass or volumetric approach. It states that C 70 is not widely used. Accuracy depends on accurate info on bulk specific gravity of the material in a SSD condition.
Summary	Due to major differences in scope and method of testing, the two are not equivalent. However the test is hardly used by Caltrans, input from district needed.	
Sieve Analysis	CTM 202 - Modified version of T 27 and other AASHTO test methods. Uses well-defined series of sieves. Oven drying of fine aggregates (<4.75 mm) needed	ASTM C 136 – 06 - Variation of AASHTO T 27. Selection of sieves left to the tester to provide better control over the info from the test. Sampling similar to CTM 202 with minor differences. Oven drying of entire sample needed although it is acceptable not to dry the coarse aggregates
	Better provisions for preventing clogging of sieve openings in fine sieves. No provisions for calculating fineness modulus	Sieving procedure similar to CTM 202 with minor differences
Summary	Despite the differences between the two tests, they may be regarded as equivalent.	
Soundness of aggregates	CTM 214 – Method of test for soundness of aggregates by use of sodium sulfate	ASTM C 88 – 05 Soundness of aggregates by use of sodium sulfate or magnesium sulfate

	Covers only the use of sodium sulfate. Uses AASHTO M 92 sieve series. Fine aggregate ranges from 4.75 mm to 150 mm. Five cycles of immersion, drying and cooling.	Includes use of sodium sulfate as well as magnesium sulfate. Sieves used vary slightly from CTM-used series. Fine aggregate ranges from 9.5 mm to 300 mm. Sample sizes smaller than CTM 214. Number of cycles of testing not specified. Reporting method very detailed and different from CTM 214.
Summary	Both tests serve the purpose of evaluating durability performance of aggregates. Results may not be comparable.	
Durability Index	CTM 229	ASTM D 3744 – 03
	Provides a measure of the relative resistance of an aggregate to producing clay-sized fines when subjected to prescribed methods of interparticle abrasion in the presence of water. The test includes 4 procedures for use with various material sizes and specific gravities. Materials larger than 19 mm to be crushed to pass the 19 mm sieve.	The test method uses a sample of coarse aggregates prepared to a specific grading and then mechanically washed. Material larger than 19 mm are discarded. This test method has 3 test procedures depending on the percentage of material > 4.75 mm or <1.18 mm. No specific procedure for lightweight aggregates.
Summary	Although the concept of the two test methods is similar, the difference in test sample preparations and applicable procedures is such that makes the results of the two tests non-comparable.	
Sand equivalent	CTM 217 – Method of test for sand equivalent	ASTM D 2419 – 02 Test method for sand equivalent value of soils and fine aggregates
	The test provides a measure of the relative proportions of detrimental fine dust or clay-like material in soil or fine aggregates. Test is performed on portion of the aggregate smaller than 4.75 mm in size. The intent is to loosen the claylike coatings from the sand particles in the test specimen.	The test method defines fine aggregates as being mostly between 4.75 mm and 75 mm in size.
Summary	Despite differences in the verbiage and details of the tests, the two appear to be closely similar and may be regarded as equivalent.	
Concrete tests		
Concrete compressive strength	CTM 521 – Method of test for compressive strength of molded concrete cylinders	ASTM C 39 – Test method for compressive strength of cylindrical concrete specimens
	The test is a modification of ASTM C 39 and AASHTO T 22.	This test has a tighter rate of loading, with max rate less than CTM and min rate higher than CTM. The test method is much more detailed than the CTM. Contains similar conversion rates for tests on specimens with non-standard length to diameter ratio.
Summary	Despite differences in the verbiage and details of the tests, the two appear to be closely similar and may be regarded as equivalent.	
Slump test	CTM 556 – Method of test for slump of fresh Portland cement concrete	ASTM C 143 – Test method for slump of hydraulic-cement concrete
Summary	The two tests have very similar language although the ASTM method has more details. The two test methods are in very good agreement and may be regarded as equivalent.	
Fresh concrete temperature	CTM 557 – Test for temperature of freshly mixed Portland cement concrete. This test method is based on ASTM C 1064.	ASTM C 1064 – Test method for temperature of freshly mixed hydraulic-cement concrete
Summary	The two test methods have very similar language and may be regarded as equivalent.	
Field making,	CTM 540 The test method identifies acceptable ways of making, handling,	ASTM C 31 This test method is more comprehensive than the CTM 540. However, it does not have provisions for

handling, and storing concrete cylinders	and storing of concrete compressive test specimens in the field. For determining the 28-day strength of non steam-cured concrete, an initial curing period of 16 to 24 hours at 16 C to 27 C is required.	identification of test cylinders. In fabricating compressive strength cylinders, ASTM test resembles closely the CTM 540. Initial curing of up to 48 hours at 16 C to 27 C required. Tighter initial curing temperature range stated for high strength concrete (> 6000 psi).
Summary	The curing condition of samples could affect the outcome of compressive strength test. The differences between the two test methods are such that they may be marginally equivalent.	
Sampling fresh concrete	CTM 539	ASTM C 172
	This test method is a simplified version of the ASTM test.	
Summary	The two tests are very similar although the ASTM test offers more details. The two tests may be regarded as equivalent.	
CT-533 Ball Penetration Method	533- Caltrans Ball Penetration Method	No comparable ASTM
Abrasive charge		ASTM has withdrawn their version (ASTM C 360) of this test method several years ago. However slump test does serve the purpose in assuring the consistency of concrete.
Summary	This can be substituted by slump test.	
CTM 543 Volumetric Method-Air Content	543- Method to measure air content	ASTM C173
Abrasive charge	ASTM has made extensive changes to this test method and is essentially a different test procedure than CT 543	
Summary	Replace CT 543 with ASTM C173 or change CT 543 to conform to ASTM C173 version.	
CTM 504 Air Content Test Pressure Method	543- Method to test air content	ASTM C231
Summary	Essentially equivalent test pressures and method; can be substituted.	
CTM 518 Unit Weight Test	518 - Unit Weight Test	ASTM C138
Abrasive charge		Test for Density Yield and Air Content
Summary	Essentially equivalent test pressures; while the test procedures are similar, the CT version may require editing to define the equipment and the sequence of operations used in the test	

Appendix 7: ***Various States Dispute Resolution Methods Comparison Table***

State	Dispute Resolution System	Acceptance Criteria	Financial Responsibilities
Arizona	If the contractor chooses to contest the compressive strength results of any sample for purposes of acceptability or improving a negative pay factor, the contractor may elect to rely on the results of compressive strengths of cores. Three cores shall be obtained at no additional cost to the Department, at the approximate location where the contested test cylinders were obtained. Such cores shall be obtained and tested in accordance with Arizona Test Method 317.	Compressive strength shall be the average of the results of the three cores. However, if the compressive strength of any one of the three cores differs by more than 10 percent from the average of the three, its result shall be discarded and the compressive strength shall be the average of the remaining two cores. Should the individual compressive strength of any two of the three cores differ by more than 10 percent from the average of the three, the results of both shall be discarded and the compressive strength shall be the result of the remaining core.	
Montana	The flexural strength results from one or a combination of the beams tested will be used to determine whether the concrete meets the required flexural strength specified by state. Flexural beams made in the field will be cast and cured using MT-101 and tested under AASHTO T 97 (ASTM C 78).	The number of flexural strength tests required for acceptance is determined by the Department on a random basis.	
Florida	The Department may initiate an IA review of the sampling and testing methods. The resolution procedure may consist of, but need not be limited to, a review of sampling and testing of fresh concrete, calculation of water to cementitious materials ratio, handling of cylinders, curing procedures and compressive strength testing. Core samples of the hardened concrete may be required. The Engineer will determine through the resolution procedure whether the QC strength test results or the verification strength test results can be relied upon.	When the verification strength test results are deemed to be the most accurate, the Department will assess a 5 percent reduction of payment for the quantity represented by the Resolution Investigation. The results of the resolution procedure will be forwarded to the Contractor within five days after completion of the investigation. If the Department finds deficiencies based on the Contractor's QCP, the Engineer may 337 suspend that part of the QCP. When the QC plan is suspended, submit corrective actions for approval to the Engineer. The Engineer may take up to five working days to review corrective actions to the QCP. The Engineer will not allow changes to contract time or completion dates.	The resolution investigation will determine the strength test results for each of the four or less LOTs. When the QC strength test results are deemed to be the most accurate, the QC strength test results will represent the four or less consecutive LOTs and the Department will pay for the resolution testing and investigation.
Iowa	When QC test results are used as part of the acceptance decision, testing disputes arising between the Contracting Agency and the Contractor shall be resolved in a reliable, unbiased manner or an evaluation performed by the Iowa DOT Central Materials Laboratory. Resolution decisions by the Iowa DOT Central Materials Laboratory will be final.	Check all numbers and calculations. Review past proficiency and validation data. Review sampling and testing procedures. Check equipment operation, calibrations and tolerances. Perform tests on split samples or reference samples. Involve the Central Materials Laboratory. If the discrepancy cannot be resolved using the steps listed above, or if it is determined that the Contractor's testing is in error, the then Agency test results will be used for the acceptance decision for that lot.	

Vermont	Following the Acceptance Decision the Contractor may request that the appropriate Agency Division Director mediate the dispute. If no agreement on the validity of the combined information (i.e. Owner and Contractor supplied) is reached, a referee sample may be sent to an independent laboratory for testing. In case of any dispute arising between the Contractor and the Owner regarding the materials furnished or the manner of performing the work, the Agency Representative has the authority to reject the materials and/or to suspend the work until the dispute is decided by the appropriate Agency Division Director.	If the Contractor decides to contest the Owner test results, the Contractor will be expected to submit any and all relevant test results including those developed by their Subcontractors or Producers, to the Owner with notification of the difference of opinion. The Owner will provide results of all acceptance sampling and testing activities to the Contractor in a timely manner. Referee samples will be performed by an independent third party laboratory selected by the Owner.	
Maryland	When past performance records are available, a standard deviation will be established from documented performance records of the producer consisting of a minimum of 15 consecutive 28 day compressive strength tests obtained within the last 12 months. The standard deviation will be established as the product of the calculated standard deviation and multiplier.	Concrete will be acceptable if both of the following requirements are met: (a) The average of all sets of three consecutive strength tests equal or exceed the specified design strength. (b) No individual strength test (average of two companion cylinders) falls below the specified design strength by more than 500 psi.	A price adjustment will be based on the Contract unit price per cubic yard of concrete. If the unit is a lump sum item, the price per cubic yard for the concrete will be determined by dividing the cubic yards into the Contract lump sum price.
Alaska		The Engineer will accept all other concrete based on conformance to the requirements for temperature, slump, air content, water cement ratio, and the specified 28-day strength for sublots as tested and determined by the Department. Each sublot will meet the specified strength requirement when both of the following conditions are met: a. Individual strength tests do not fall below the specified strength by more than 12.5% or 500 psi, whichever is least. b. An individual strength test averaged with the two proceeding individual strength tests meets or exceeds specified strength (for the same class of concrete on the same contract)	The quantities of reinforcing steel and other contract items included in cast-in-place structures will be measured for payment as prescribed for the items involved. Payment for reinforcing steel, prestressing steel, and other items included in precast concrete members is subsidiary to the Contract price for the member. Joint filler is subsidiary to concrete. Payment for concrete that fails to meet minimum acceptance levels for strength will be adjusted according to the following formula. Pay adjustment = -2(f'c-fc)(PAB)(Q)

Arkansas	Any unresolved disputes arising under the Contract shall be submitted by the Contractor in writing to the Department's Resident Engineer. Disputes claiming additional compensation shall contain the information set forth in Subsection 105.18(a) and (b). The Resident Engineer shall render a written decision within 60 calendar days of receipt of the Contractor's letter and information. Should a dispute not be resolved by the written decision of the Resident Engineer, subsequent appeal by the Contractor shall be submitted in writing within 60 calendar days of the decision of the Resident Engineer, and shall be addressed directly to the Chief Engineer. The Chief Engineer shall render a decision on the matter in writing to the Contractor within 60 calendar days after receipt of the Contractor's written request for dispute resolution. The ruling by the Chief Engineer shall be final and conclusive unless, within 180 calendar days from the date of issuance of the Chief Engineer's decision, the Contractor files a claim with the Arkansas State Claims Commission appealing the decision of the Chief Engineer. In connection with any appeal proceeding under this clause, the Contractor shall be afforded an opportunity to be heard and offer evidence in support of an appeal before the Arkansas State Claims Commission, subject to the rules and regulations of the Claims. Commission and Ark. Code Ann. § 19-10-302 which require pursuit and exhaustion of all remedies against responsible third parties and insurance coverage. Pending final decision of a dispute hereunder, the contractor shall proceed diligently with the performance of the Contract and in accordance with the Chief Engineer's decision	As soon as practical after completion of the entire project, including receipt of all required documentation, the Engineer will make an inspection. If all construction provided for and contemplated by the Contract is found to have been satisfactorily completed, that inspection shall constitute the final inspection and the Engineer will make the final acceptance and notify the Contractor in writing of this acceptance as of the date of the final inspection. If, however, the inspection discloses any work, in whole or in part, as being unsatisfactory, the Engineer will advise the Contractor of the work requiring correction. The Contractor shall immediately make the required corrections. Upon correction of the work, another inspection will be made which shall constitute the final inspection provided the work has been satisfactorily completed. In such event, the Engineer will make the final acceptance and notify the Contractor in writing of this acceptance as of the date of final inspection.	If in any case, the Contractor deems that additional compensation is due for work or material not clearly covered in the Contract or not ordered by the Engineer as extra work, as defined in Subsection 104.04, the Contractor shall notify the Engineer in writing of intention to make claim for such additional compensation before beginning the work on which the claim is based. If such notification is not given and the Engineer is not afforded proper time and facilities by the Contractor for keeping accurate account of the actual costs of the work, the Contractor hereby agrees to waive any claim for such additional compensation. Such notice by the Contractor and the fact that the Engineer has kept account of the cost of the work shall not in any way be construed as proving or substantiating the validity of the claim. If the claim, after consideration by the Engineer, is found to be just and adequately supported, an adjustment will be made to the Contract. If the Contract does not contain a pay item for which the adjustment can be made, the adjustment will be made according to Subsection 109.04.

Wyoming	Quality Control and Quality Assurance personnel are to meet and review testing procedures, equipment condition, sampling techniques, and equipment calibrations. The Department's Materials Program may be contacted for assistance. Perform the correlation again if cause for bias can be determined and corrected. If the second slump, air content or unit weight tests are not within the allowable difference, area personnel from the Materials Program Independent Assurance section or another party agreed upon by both the contractor and the department will be contacted by the engineer. A third correlation evaluation will be performed with testing being conducted by all three parties. The Independent Assurance (IA) tests results will confirm either the contractor's or the department's testing depending on which results the IA results are closest to. If the third party test results verify the contractor's results, the department will pay for the third party testing. If department's test results are verified the contractor shall pay for the testing.	Comparison of the engineer's quality assurance test results with specification limits using independent samples obtained randomly (except where otherwise noted) for: a. Slump b. Air content c. Fine aggregate gradation d. Coarse aggregate gradation e. Compressive strength When compressive strength test specimens are made, slump and air content tests along with unit weight and temperature determinations are be made, all from the same sample of concrete. Stockpile moisture contents may be tested by the engineer for comparison to the moisture test results being used to adjust batch water and determine the water/cement or water/cement + fly ash ratio. For any Level of Control, concrete with the slump outside the specification limits will be cause for rejection of the load of concrete. Make immediate adjustments to the mixture. The engineer has the option to test and reject material that is obviously outside of specification limits.2. For Level I Control, the engineer will determine a pay factor on each lot based on independent samples for: a. Air content b. Compressive strength A pay factor determination is made when there is sufficient quantity to provide the minimum number of test results required to constitute a lot. Partial lot test results will be included with the previous lot for analysis.	For Level II and III Control, the engineer will determine a pay factor on each quality acceptance sample. The pay factor will be applied to the volume of concrete represented by each sample. Per Table II, the maximum amount of concrete represented by an individual sample is 100 CY. The amount of concrete represented by each sample is dependent on the sampling frequency. The volume of concrete represented by each sample is the volume of concrete placed since the previous Quality Acceptance test. If a Quality Acceptance test is not taken for the final load, use the pay factor from the last Quality Acceptance test taken. 4. For Level IV Control, the engineer will accept/reject with no pay factor.
Mississippi	Disputes over variations between Contractor's QC test results and the Department's QA test results shall be resolved at the lowest possible level. When there are significant discrepancies between the QC test results and the QA test results, the Contractor's Quality Control Manager, the Project Engineer, and/or the District Materials Engineer shall look for differences in the procedures, and correct the inappropriate procedure before requesting a third party resolution. If the dispute cannot be resolved at the project or District level, the Department's Central Laboratory will serve as a third party to resolve the dispute. The Central Laboratory's decision shall be binding. The Contractor shall be responsible for the cost associated with the third party resolution if the final decision is such that the Department's QA test results were correct. Likewise, the Department will be responsible for the cost when the final decision is such that the Contractor's QC test results were correct.	Acceptance of a production lot will be made if the compressive strength test result is greater than or equal to 4,000 psi. If the compressive strength test result is less than 4,000 psi, then the acceptance of the production lot will be based on its meeting the following acceptance criteria in its entirety: a) 90 percent of the compressive strength test results for the overall production exceeds 4,150 psi b) The average of any six consecutive compressive strength test results exceeds 4,250 psi c) No individual compressive strength test result falls below 3,600 psi Units shall be rejected because of failure to meet any or all of the requirements specified above. In addition, any or all of the following defects shall be sufficient cause for rejection. a) Defects that indicate imperfect molding b) Defects indicating honeycombed or open texture concrete c) Cracked or severely chipped panels d) Color variation on from face of panel due to excess form oil or other reasons	The Department will assume the cost of acceptance sampling and testing during production and use of the materials.

Delaware	When there is a significant alleged discrepancy regarding the Engineer's acceptance test results, the Contractor must claim a dispute within two operational days of the test date. The Engineer and the Contractor will review the sample quality, the test method, the laboratory equipment, and the laboratory technician. If these factors are not the cause of the dispute, a third party dispute resolution will be used. For third party resolution testing, it can be either at another Contractor's laboratory, the Engineer's laboratory, or an independent accredited laboratory. Unless otherwise mutually agreed upon by DAPA and the Engineer, the Engineer's qualified laboratory in Dover and qualified personnel shall conduct the necessary testing for third party Dispute Resolution after the Engineer has provided reasonable notice to allow the Contractor to witness this testing.	When disputes over production testing occur, the samples used for Dispute Resolution testing will be those samples the Contractor properly captured, labeled, and stored, as described in the second paragraph of the section of these specifications titled .05 Acceptance Plan, (a) Material Production – Tests and Evaluations. If no samples are available, the original testing results will be used for payment calculations.	If there is a discrepancy between the Engineer's acceptance test result and the Contractor's test result, the Contractor may ask for the Dispute Resolution sample to be tested. If the Dispute Resolution sample substantiates the original acceptance test result, the Contractor, after two such Dispute Resolution samples, will be charged a fee of $125 for all further Dispute Resolution cores that substantiate the acceptance test result. If the Dispute Resolution sample substantiates the Contractor's test result, the Contractor will not be charged a fee.
Texas	When QC test results are used in the acceptance decision, testing disputes arising between TxDOT, or its designated agents, and the contractor shall be resolved in a reliable, unbiased manner by referee testing or evaluation performed by the Construction Division, Materials & Pavements Section (CST/M&P) central laboratory. The decision by the CST/M&P central laboratory will be final.	Contractor-performed QC sampling and testing may be used as part of an acceptance decision when required or allowed by specification. These QC test results shall be validated by verification test results obtained from independently taken samples. Qualified TxDOT personnel or their designated agents shall perform verification sampling and testing.	

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TABLE 3 Limits for Deleterious Substances and Physical Property Requirements of Coarse Aggregate for Concrete

NOTE 1—See Fig. 1 for the location of the weathering regions and Note 9 for guidance in using the map. The weathering regions are defined as follows:

(S) Severe Weathering Region—A cold climate where concrete is exposed to deicing chemicals or other aggressive agents, or where concrete may become saturated by continued contact with moisture or free water prior to repeated freezing and thawing.

(M) Moderate Weathering Region—A climate where occasional freezing is expected, but where concrete in outdoor service will not be continually exposed to freezing and thawing in the presence of moisture or to deicing chemicals.

(N) Negligible Weathering Region—A climate where concrete is rarely exposed to freezing in the presence of moisture.

Class Designation	Type or Location of Concrete Construction	Maximum Allowable, %						
		Clay Lumps and Friable Particles	Chert (Less Than 2.40 sp gr SSD)	Sum of Clay Lumps, Friable Particles, and Chert (Less Than 2.40 sp gr SSD)	Material Finer Than 75-µm (No. 200) Sieve	Coal and Lignite	Abrasion[A]	Magnesium Sulfate Soundness (5 cycles)[B]
			Severe Weathering Regions					
1S	Footings, foundations, columns and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	...	...	1.0[C]	1.0	50	...
2S	Interior floors without coverings	5.0	...	...	1.0[C]	0.5	50	...
3S	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	5.0	7.0	1.0[C]	0.5	50	18
4S	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures, subject to frequent wetting	3.0	5.0	5.0	1.0[C]	0.5	50	18
5S	Exposed architectural concrete	2.0	3.0	3.0	1.0[C]	0.5	50	18
			Moderate Weathering Regions					
1M	Footings, foundations, columns, and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	...	...	1.0[C]	1.0	50	...
2M	Interior floors without coverings	5.0	...	...	1.0[C]	0.5	50	...
3M	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	8.0	10.0	1.0[C]	0.5	50	18
4M	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures subject to frequent wetting	5.0	5.0	7.0	1.0[C]	0.5	50	18
5M	Exposed architectural concrete	3.0	3.0	5.0	1.0[C]	0.5	50	18
			Negligible Weathering Regions					
1N	Slabs subject to traffic abrasion, bridge decks, floors, sidewalks, pavements	5.0	...	...	1.0[C]	0.5	50	...
2N	All other classes of concrete	10.0	...	...	1.0[C]	1.0	50	...

[A] Crushed air-cooled blast-furnace slag is excluded from the abrasion requirements. The rodded or jigged bulk density (unit weight) of crushed air-cooled blast-furnace slag shall be not less than 1120 kg/m^3 [70 lb/ft^3]. The grading of slag used in the bulk density (unit weight) test shall conform to the grading to be used in the concrete. Abrasion loss of gravel, crushed gravel, or crushed stone shall be determined on the test size or sizes most nearly corresponding to the grading or gradings to be used in the concrete. When more than one grading is to be used, the limit on abrasion loss shall apply to each.

[B] The allowable limits for soundness shall be 12 % if sodium sulfate is used.

[C] This percentage under either of the following conditions: (*1*) is permitted to be increased to 1.5 if the material is essentially free of clay or shale; or (*2*) if the source of the fine aggregate to be used in the concrete is known to contain less than the specified maximum amount passing the 75-µm (No. 200) sieve (Table 1) the percentage limit (*L*) on the amount in the coarse aggregate is permitted to be increased to $L = 1 + [(P)/(100 - P)]\,(T - A)$, where P = percentage of sand in the concrete as a percent of total aggregate, T = the Table 1 limit for the amount permitted in the fine aggregate, and A = the actual amount in the fine aggregate. (This provides a weighted calculation designed to limit the maximum mass of material passing the 75-µm (No. 200) sieve in the concrete to that which would be obtained if both the fine and coarse aggregate were supplied at the maximum tabulated percentage for each of these ingredients.)

90-1.01D(5) Compressive Strength

90-1.01D(5)(a) General

Section 90-1.01D(5) applies ~~for~~ to either of the following cases:

1. *Concrete is designated by compressive strength.*
2. *Attaining a minimum concrete compressive strength is specified as a prerequisite to applying loads or stresses to a concrete structure or member.*

If the 28-day compressive strength described is 3,600 psi or greater, the concrete is designated by compressive strength.

If the concrete is designated by compressive strength, the strength of concrete that is not steam cured is determined from cylinders cured under ~~Method 1 of California Test 540~~ASTM C31.

If attaining a minimum concrete compressive strength is specified as a prerequisite to applying loads or stresses to a concrete structure or member, cylinders for concrete that ~~is~~ are not steam cured are cured under ~~Method 1 of California Test 540~~ASTM C31 and the concrete compressive strength is evaluated based on individual tests.

For concrete with a described 28-day compressive strength greater than 3,600 psi, 42 days are allowed to attain the strength described.

Except for concrete specified to be in a freeze-thaw area, 56 days are allowed to attain the strength described if the cementitious material satisfies the following equation:

$$[(41 \times UF) + (19 \times F) + (11 \times SL)]/TC \geq 7.0$$

where:

F = natural pozzolan or fly ash complying with AASHTO M 295, Class F or N, including the quantity in blended cement, lb/cu yd. F is equivalent to the sum of FA and FB as defined in section 90-1.02B(3).

SL = GGBFS, including the quantity in blended cement, lb/cu yd

UF = silica fume, metakaolin, or UFFA, including the quantity in blended cement, lb/cu yd

TC = total quantity of cementitious material used, lb/cu yd

For concrete satisfying the equation above, test for the compressive strength at least once every ~~500~~ 100 cubic yard or one day of pour at 28, 42, and 56 days. Submit the test results to the Engineer and to METS, Attention: Office of Structural Materials, Concrete Materials Testing Branch.

The Engineer determines the concrete compressive strength from test cylinders:

1. *Made from concrete sampled under ~~California Test 539~~ASTM C172*
2. *Molded and initially field cured under ~~California Test 540~~ASTM C31*
3. *Cured and tested under ~~California Test 521~~ASTM C39*

A compressive strength test represents no more than ~~300~~ 100 cu yd of concrete and consists of the average compressive strength of ~~2~~ two cylinders made from material taken from a single load of concrete. If a cylinder shows evidence of improper sampling, molding, or testing, the cylinder is discarded and the test consists of the compressive strength of the remaining cylinder.

If a single compressive strength test result, for either QC or QA, is below the strength described at the maximum age specified or allowed, or if the compressive strength of concrete tested at ~~7~~ seven days indicates to the Engineer that the concrete will not attain the strength described at the maximum age specified or allowed, correct the mix design or concrete fabrication procedures and obtain authorization before you place additional concrete.

If a single compressive strength test result, for either QC or QA, is below the strength described at the maximum age specified or allowed, the concrete represented by the test is subject to one of the following actions:

1. *If the compressive strength is at least 95 percent of the strength described, $10 per cubic yard of concrete is deducted.*
2. *If the compressive strength is below 95 percent of the strength described but is at least 85 percent of the strength described, $15 per cubic yard of concrete is deducted.*
3. *If the compressive strength is below 85 percent of the strength described, the concrete is rejected and Caltrans may require removal or repair of ~~you must remove~~ the in-place concrete.*

If either of QC or QA~~a~~ strength test results at the maximum age specified or allowed is below the strength described but is at least 85 percent of the strength described, the deductions specified above apply unless ~~you~~ the QCM obtains and submits evidence that the strength of the concrete placed in the work is greater than or equal to the strength described, and this evidence is accepted by the Engineer.

If either of QC or QA~~a~~ strength test results at the maximum age specified or allowed is below 85 percent of the strength described, you must remove the concrete represented by the test unless ~~you~~ the QCM obtains and submits evidence that the strength of the concrete placed in the work is at least 85 percent of the strength described and this evidence is accepted by the Engineer.

If the evidence consists of tests made on cores taken from the work, obtain and test the cores under ASTM C 42.

90-1.02C Aggregates

90-1.02C(1) General

If either of QC or QA~~the~~ results of any ~~1~~ one or more of the cleanness value, sand equivalent, or aggregate grading tests do not comply with the requirements for operating range, but all comply with the requirements for contract compliance:

1. *Suspend the concrete placement at the completion of the current pour.*
2. *Do not restart the concrete placement until test results or other information show that the ~~next material~~ supply to be used in the work complies with the requirements for operating range.*

If either of QC or QA~~the~~ results of either or both of the cleanness value and coarse aggregate grading tests do not comply with the requirements for contract compliance, the concrete is rejected and Caltrans may require~~you must~~ removal of~~e~~ the in-place concrete represented by the tests. However, if the Engineer determines that the concrete is structurally adequate, the concrete may remain in place and $3.50 per cubic yard for paving concrete and $5.50 per cubic yard for other concrete is deducted for the concrete represented by these tests and left in place.

If the results of either or both of the sand equivalent and fine aggregate grading tests do not comply with the requirements for contract compliance, you must remove the concrete represented by the tests. However, if the Engineer determines that the concrete is structurally adequate, the concrete may remain in place and $3.50 per cubic yard for paving concrete and $5.50 per cubic yard for other concrete is deducted for the concrete represented by these tests and left in place.

The ~~2~~ two preceding paragraphs apply individually to the contract compliance requirements for coarse and fine aggregate. If both coarse and fine aggregate do not comply with the contract compliance requirements, both paragraphs apply. The deductions specified in those paragraphs are in addition to any deductions made under section 90-1.01D(2).

90-1.02C(2) Coarse Aggregate

Coarse aggregate must consist of gravel, crushed gravel, crushed rock, reclaimed aggregate, crushed air-cooled iron blast furnace slag, or a combination of these.

Do not use crushed air-cooled iron blast furnace slag in reinforced or prestressed (PS) concrete.

Reclaimed aggregate must comply with the specifications for aggregate.

Coarse aggregate must comply with the requirements shown in the following table:

Property	California TestASTM	Requirement
Loss in Los Angeles rattler after 500 revolutions	211	45 percent max
Cleanness value% fines below 75 micron-sieve		
Operating range	227C117	75 min1.5 percent
Contract compliance	227C117	71 min2 percent

Table 3 - Coarse Aggregate Requirements

For cleanness value, an operating range limit of 71 minimum1.5 percent and a contract compliance limit of 68 minimum2.5 percent apply if you submit a certificate of compliance certifying that:

1. Coarse aggregate sampled at the completion of processing at the aggregate production plant had a cleanness percent fine below one percentvalue of at least 82 when tested under California Test 227ASTM C117.
2. Prequalification tests performed under California Test 549 showed that the aggregate would develop a relative strength of at least 95 percent and have a relative shrinkage of no more than 105 percent based on concrete

90-1.02C(3) Fine Aggregate

Fine aggregate must consist of natural sand, manufactured sand produced from larger aggregate, or a combination of these. Manufactured sand must be well graded.

Fine aggregate must comply with the requirements shown in the following table:

Property	California TestASTM	Requirement
Organic impurities	213	Satisfactory[a]
Sand equivalent:		
Operating range	217D2419	75 minimum
Contract compliance	217D2419	71 minimum

[a] Fine aggregate that develops a color darker than the reference standard color may be authorized if 95 percent relative mortar strength is achieved when tested under ASTM C 87.

Table 4 - Fine Aggregate Requirements

For sand equivalent, an operating range limit of 71 minimum and a contract compliance limit of 68 minimum apply if you submit a certificate of compliance certifying that:

1 Fine aggregate sampled at the completion of processing at the aggregate production plant had a sand equivalent value of at least 82 when tested under California Test 217ASTM D2419.
2. Prequalification tests performed under California Test 549 showed that the aggregate would develop a relative strength of at least 95 percent and have a relative shrinkage of no more than 105 percent based on concrete

REFERENCES

1. "Quality Assurance Program: Quality Control Sampling and Testing." *Search*. Web. 07 May 2011. <http://onlinemanuals.txdot.gov/txdotmanuals/qap/quality_control_sampling_and_testing.htm>.
2. "Arkansas 2003 Standard Specification for Highway Construction." *Arkansas State Highway and Transportation Department*. Web. 20 Apr. 2011. <http://www.arkansashighways.com/standard_spec_2003.aspx>.
3. "Wyoming Department of Transportation Supplementary Specification for Structural Concrete with Quality Control and Quality Assurance Acceptance" Wyoming Department of Transportation, Web. 21 Apr. 2011. <http://www.dot.state.wy.us/webdav/site/wydot/shared/Construction/2010%20Supplemental%20Specifications/Division%20500/SS-500G_Structural%20Concrete%20with%20Quality%20control%20and%20Quality%20Acceptance.pdf>
4. "Mississippi Standard Specifications for Road and Bridge Construction." Mississippi Department of Transportation, Web. 25 Apr. 2011. <http://www.gomdot.com/Divisions/Highways/Resources/Construction/pdf/2004StandardSpecs/specbook.pdf>
5. "Quality Assurance Program: Quality Control Sampling and Testing." *Search*. Web. 26 May 2011. <http://onlinemanuals.txdot.gov/txdotmanuals/qap/quality_control_sampling_and_testing.htm>.
6. "Directory of Approved Materials Testing Laboratories." Arizona Department of Transportation, Web. 8 May. 2011. <http://www.azdot.gov/Highways/Materials/QA/PDF/Directory_of_Approved_Labs.pdf>.
7. "QC/QA: Evaluation of Effectiveness in Kentucky." University of Kentucky, College of Engineering, Web. 25 Apr. 2011. <http://www.ktc.uky.edu/Reports/KTC_08_19_SPR_347_07_1F.pdf>
8. "Materials Sampling Guide." State of Nebraska department of Roads Materials and Research Divisions, Web, 5 May. 2011. <http://www.dor.state.ne.us/mat-n-tests/matsampguide/sampguide01-01-11.pdf >
9. " Procedures for Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)." Tennessee Department of Transportation Division of Materials and Tests, Web. 6 May. 2011. <http://www.tdot.state.tn.us/materials/fieldops/sop/1-0%20Sampling%20and%20Testing%20Intro%20Guide%20and%20Schedule%203-14-07.pdf>
10. "Quality Assurance Program: Acceptable Tolerance Limits for Independent Assurance." *Search*. Web. 25 Mar. 2011. <http://onlinemanuals.txdot.gov/txdotmanuals/qap/acceptable_tolerance_limits_for_independent_assurance.htm>.
11. "Materials Quality Assurance (QA) Stewardship Review of the Virginia Department of Transportation(DOT)", Federal Highway Administration, Web. 25 Mar. 2011. <http://www.fhwa.dot.gov/vadiv/materialsqualityassurance.pdf>
12. "Test Methods for Construction Inspection", Indiana Department of Transportation, Web. 7 Apr. 2011. <http://www.in.gov/indot/files/QualifiedTechnicianTestMethods.pdf>
13. "Qualified Laboratory and Technician Program", Indiana Department of Transportation, Web. 7 Apr. 2011. <http://www.in.gov/indot/files/QualifiedTechnicianProgram.pdf>
14. "Special Provision for Quality Control/Quality Assurance Specifications for Hot Mixed Asphalt Concrete Pavement", State of South Dakota Department of Transportation, December 10, 2007. Web. 7 Apr. 2011. <http://www.sddot.com/operations/docs/SpecProv04/QCQA.pdf>
15. McLawhorn, Nina. "Alternative Dispute Resolution." Prepared for Bureau of Highway Construction Division of Transportation Infrastructure Development. CTC & Associates LLC, WisDOT RD&T

Program, February, 2003. Web. 7 Apr. 2011. <http://on.dot.wi.gov/wisdotresearch/database/tsrs/tsralternativedisputeresolution.pdf>

16. Willoughby, Kathy. "Transportation Synthesis Report, Contractor QA/QC and Workforce Implicaations for State DOT's." *WSDOT Research Office* (2006). Web. 15 May 2011. <http://www.wsdot.wa.gov/NR/rdonlyres/03B669BE-25E5-4440-883F-06127BB27C07/0/ContractorQA_QCandWorkforceEffectivenessSynthesisSept06.pdf>.
17. "Division 1: General Requirements, Section 01450, Contractor Quality Control", Florida Department of Transportation, Web. 17 Apr. 2011. <http://bcs.dep.state.fl.us/env-prmt/walton/pending/0279461_001_JC(30-A_Beach_Restoration)/Application/Attachment%20E%20-%20Draft%20Technical%20Specifications%20-%20Separated%20Sectio/01450%20Contractor%20Quality%20Control.pdf>
18. "Section 501 Portland Cement Concrete Pavement", Montana Department of Transportation, Web. 9 May. 2011. <http://www.mdt.mt.gov/other/contract/external/standard_specbook/2006/division_500.pdf >
19. "Part 6 – Structures, Section 601 – Timber Structures", Tennessee Department of Transportation, Web. 19 Apr. 2011. <http://www.mdt.mt.gov/other/contract/external/standard_specbook/2006/division_500.pdf >
20. "Division II – Materials", State of Virginia Department of Transportation, Web. 25 Mar. 2011. <http://www.virginiadot.org/business/resources/const/07RevDiv_II.pdf>
21. "Contract Claim Procedure." *Texas Administrative Code*. Texas Department of Transportation. Web. 12 Apr. 2011. <http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=43&pt=1&ch=9&rl=2>.
22. "Quality Control Plan for District Three Design." *Florida Department of Transportation Cipley, Florida* (2003). Print.
23. "Quality Control and Quality Assurance Plan for State and Local Jurisdiction Bridge Safety Inspection - National Bridge Inspection Standards - Bridge - FHWA." *Home | Federal Highway Administration*. Web. 27 Mar. 2011. <http://www.fhwa.dot.gov/bridge/nbis/qainspections.cfm>.
24. ACI Committee 301. "ACI 301-10 Specifications for Structural Concrete." American Concrete Institute, Dec. 2010. Web. 12 Apr. 2011.
25. NRMCA. "Guide to Improving Specifications for Ready Mixed Concrete." *NRMCA Publication 2PE003*. May 2009. Web. 13 Apr. 2011.
26. Obla, Karthik, and Colin Lobo. "Experimental Case Study Demonstrating Advantages of Performance Specifications." *RMC Research Foundation*. Jan. 2006. Web. 10 Apr. 2011. <http://www.rmc-foundation.org/images/P2P%20Lab%20Report%20Jan2006.pdf>.
27. Doty, R. N. *Quality Control/Quality Assurance, Materials Sampling and Testing*. Tech. no. Task Group. Print.
28. Daniel, Gene. "NRMCA Plant Inspection Guide." *NRMCA Certification of Ready Mixed Concrete Production Facilities* (2007). Print.
29. ACI Committee 311. "ACI Manual." *ACI Manual of Concrete Inspection* SP-2(07) (2007). Print.
30. "Quality in the Constructed Project." Manuals and Reports on Engineering Practice No. 73. Print.