

# RECLAMATION

*Managing Water in the West*

Technical Memorandum No. MERL-2015-073

## Quality Management Plan Guidance for Concrete used for Construction of Significant Features



U.S. Department of the Interior  
Bureau of Reclamation  
Technical Service Center  
Denver, Colorado

August 2015

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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**BUREAU OF RECLAMATION**  
**Technical Service Center, Denver, Colorado**  
**Materials Engineering and Research Laboratory, 86-68180**

**Technical Memorandum No. MERL-2015-073**

# **Quality Management Plan Guidance for Concrete used for Construction of Significant Concrete Features**

*by*

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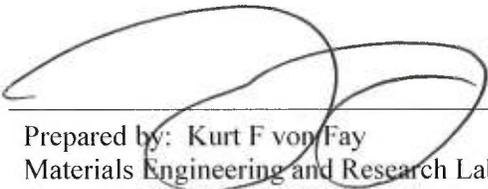


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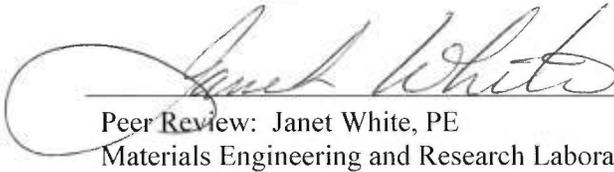
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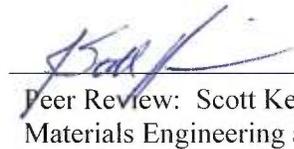
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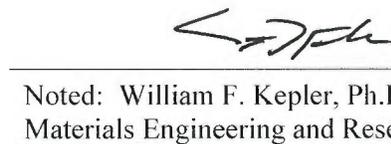
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### Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
CCRL	Cement and Concrete Reference Laboratory
CDTM	concrete materials design team member
cm	cementitious materials
COR	Contracting Officer's Representative
ER	Engineer Regulation
FAR	Federal Acquisition Regulation
F/T	freezing and thawing
f'c	design strength
IBC	International Building Code
JHA	Job Hazard Analysis
PCQAS	Project Concrete Quality Assurance System
Psi	pounds per square inch
QA	quality assurance
QC	quality control
QMP	quality management plan
Reclamation	Bureau of Reclamation
RCC	roller compacted concrete
RSHA	Reclamation Safety and Health Standards

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RSN	Required submittal number
Vebe	Vibratory consistency
w	water
WRA	water-reducing, set-controlling admixtures

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# Quality Management Plan Guidance for Concrete used for Construction of Significant Concrete Features

## I. Project Quality Management Plan Summary

This project quality management plan (QMP) guidance document provides information about concrete material related quality assurance (QA) and quality control (QC) practices for the Bureau of Reclamation (Reclamation) construction projects with significant concrete features. It is intended to serve as a guide for developing a QMP for concrete used for construction of significant concrete features of a project. It is up to the design and project management team to determine when to use this document; they must decide when the concrete structure is significant and when QMP documents (project-specific QC and QA procedures) are appropriate for a project. This document provides information about what to include and items to consider for QC and QA planning.

Generally speaking, QC activities are those actions performed by the contractor to ensure that the product meets specification requirements. QA activities are those actions performed by the Government to ensure that the contractor is following specification requirements.

### A. Quality

Quality is the adherence and conformance to properly developed requirements.

Requirements for quality design in concrete construction include conformance with applicable codes, standards, guidance, regulations, laws, and statutes referenced in the specifications.

Requirements for quality construction include compliance with contract provisions, clauses, and specifications. These contract documents establish the quality requirements for construction by defining the standards, including salient and essential characteristics, of concrete materials and the acceptance criteria and necessary testing inspection of concrete construction.

### B. Quality Management

Quality management is the combination of all QA and QC activities used to attain the quality required for the contract deliverables. Quality management includes

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all planned and systematic actions necessary to provide confidence that all products and constructed works will meet established parameters and perform satisfactorily in service.

Quality management is the responsibility of Reclamation and the contractor; quality management must be achieved through cooperation and collaboration.

The QMP will depend on the type of concrete structure being built. As the complexity and uniqueness of the feature being constructed increases, the specifications may need to be more prescriptive rather than performance based. More prescriptive specifications may require that the Government, for example, design the concrete mixture, and determine how and when the concrete will be placed and cured. Many times, for these specifications, the cementitious materials (cm, cement plus pozzolan) are paid for separately from other concrete ingredients, allowing for QA staff to adjust concrete mixture proportions without undue impacts on the contractor concrete costs. A more prescriptive concrete specification lowers the risk for the contractor, perhaps lowering their concrete costs, but will also require additional QA staff for the Government.

On the other hand, a performance based specification provides details about the required concrete product, and allows the contractor greater latitude in developing the concrete mixture, placing plan, schedule, etc. This may result in savings, since the contractor will be motivated to produce and place the concrete at as low a cost as possible. This type of specification requires a higher level of effort by the contractor for QC. This contract type is also somewhat riskier for the contractor, since they have much more responsibility for the final product.

## **II. Roles and Responsibilities**

### **A. Quality Assurance**

This document is intended to provide guidance for project QA operations related to concrete production performed by or for the Government. The QMP should include a listing of the work requiring surveillance (inspection and testing), requirements, methods, and frequencies of surveillance, along with workload, staffing, job responsibilities, qualifications, training, certifications, inspection, testing, and documentation. No document, however, can take the place of proper field and laboratory training.

Numerous activities are required as a part of a comprehensive concrete QA program. Prior to the start of design and construction, the QA involves locating sources of materials suitable for use for the construction and performing the

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necessary investigations to evaluate the durability exposure conditions of the concrete, such as sulfate attack, freezing and thawing exposure, and potential for alkali-aggregate reaction. The design engineer, in consultation with the area office representative and the contracting officer, is responsible for developing designs and specifications in accordance with industry standards. For concrete design, the American Concrete Institute (ACI) 318-14<sup>1</sup> includes requirements for assuring concrete mixtures meet both minimum strength and durability criteria as a part of the design process.

After the contract award, Reclamation or the owner's representative is responsible for QA to the extent required to determine whether the contractor has fulfilled the contract requirements, and will confirm that the specified deliverables are obtained. QA may include inspection, monitoring, sampling, checking, destructive and non-destructive testing, peer and independent reviews, third party verification, and may be based on statistical methods, empirical observations, and/or other specification requirements.

Reclamation QA is for the sole benefit of Reclamation and does not:

- Relieve the contractor of responsibility for providing minimum required QC throughout the construction period,
- Relieve the contractor of responsibility for damage or loss of supplies before acceptance under the terms of the contract, or
- Affect the continuing rights of Reclamation after acceptance of the completed work as stipulated in the contract requirements.

Reclamation is required, as part of its QA responsibilities, to monitor and assure that the contractor is in compliance with contract documents and fulfilling contractual responsibilities in performance of QC, as defined by contract.

Federal Acquisition Regulation (FAR) 46.4 defines *Government contract quality assurance* as “the various functions, including inspection, performed by the Government to determine whether a contractor has fulfilled the contract obligations pertaining to quality and quantity.” Section 46.401 (e) goes on to state that “Government inspection shall be performed by or under the direction or supervision of Government personnel.”<sup>2</sup>

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<sup>1</sup> ACI 318-14 Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute, Farmington Hills, MI, 2014.

<sup>2</sup> Federal Acquisition Regulation (FAR), Volume I, Part 46, March 2015.

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FAR 52.246-12<sup>3</sup> states that “Government inspections and tests are for the sole benefit of the Government and do not relieve the contractor of responsibility for proving adequate quality control measures.”

For civil works structures, the United States Army Corps of Engineers regulations require the use of Government personnel to perform QA activities:

“The inclusion of quality control requirements for the contractor does not relieve the Contracting Officer of the responsibility for safeguarding the Government’s interests.... The GQA [Government Quality Assurance] responsibility is not to be imposed on the construction contractor. If personnel shortages preclude the use of government personnel to accomplish GQA, it should be done by a commercial testing organization under contract to the Government.”<sup>4</sup>

“Subsequent to contractor quality control completion inspections, acceptance inspections of completed construction are a government responsibility.”<sup>5</sup>

For commercial projects, the International Building Code (IBC)<sup>6</sup> also requires QA inspection and testing for critical building infrastructure to be the responsibility of the owner. “The owner or the registered design professional in responsible charge acting as the owner’s agent shall employ one or more special inspectors to provide inspections during construction.”

The ACI 318-14 Building Code<sup>1</sup> requires inspection of concrete structures and references ACI 311 “Guide for Concrete Inspection” which includes specific requirements for acceptance testing as a part of the overall QA program. ACI recommends that acceptance testing be performed by the owner or engineer as a part of the overall QA program, and goes as far as saying “[t]he owner or engineer should avoid the undesirable practice of arranging payment for acceptance inspection and testing services through the contractor. Such practice is not in the owner’s interest.”<sup>7</sup>

Although the IBC<sup>6</sup> and ACI 318-14<sup>1</sup> codes contain standards for buildings, most large civil projects designed and built in the private sector follow these standards.

The ACI 318-14 Building Code<sup>1</sup> specifies minimum criteria for frequency of testing of structural concrete. Industry standards provide additional guidance for

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<sup>3</sup> Federal Acquisition Regulation (FAR), Volume I, Part 52, July 2015.

<sup>4</sup> U.S. Army Corps of Engineers, Engineering Manual (EM) 1110-2-2000, “Standard Practice for Concrete for Civil Works Structures,” February 1, 1994.

<sup>5</sup> U.S. Army Corps of Engineers, Regulation ER 1180-1-6 Construction Quality Management dated September 30, 1995.

<sup>6</sup> International Building Code, International Code Council, 2012.

<sup>7</sup> ACI 311.4R-05, “Guide for Concrete Inspection,” American Concrete Institute.

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recommended tests and frequency of testing for structural and other concretes. Normally, this includes daily sampling and testing of each class of concrete. The extent of QA needs to be commensurate with the value, complexity, sensitivity, criticality, and other factors of the contract requirements.

Contract specifications detail the level of quality necessary to achieve the minimum standards for meeting the design requirements. The project team will assure these standards are met and that the contractor uses standard and/or specified methods to produce satisfactory results, or that if unusual methods are used that these methods achieve satisfactory results.

Much of Reclamation's specification for concrete deals with testing materials and ensuring the properties meet specification requirements. However, before concrete is placed, the specification requirements regarding excavation, formwork, steel reinforcement, and construction joints must be inspected. Inspectors must familiarize themselves with the specifications, including relevant drawings. Daily reports should be prepared that document observations made during the inspection of the placement of steel reinforcement and formwork. Required excavations should be verified by inspection and testing, and appropriate reports prepared.

Excavated areas should be inspected to ensure the excavations meet project requirements, including removal of detrimental materials, such as excess dirt, debris, water, ice, and snow. In hot weather, to ensure quality concrete, it may be necessary to cool and moisten surfaces to determine which concrete will be used.

Prior to placing concrete in formwork, forms should be inspected to ensure they meet specification requirements, including size, location, and dimensions. The forms should be clean of foreign materials (dirt, dried mortar, oil, grease, water, ice, etc.) and free of excess quantities of form release agents. Forms need to be mortar-tight and sufficiently strong to maintain their position and shape. Forms should be monitored during concrete placement to ensure that no movement, leakage, or damage occurs.

Before reinforcement is placed, inspection of surfaces to ensure the reinforcement is free from objectionable materials, including heavy corrosion. All loose rust or mill scale must be removed, but a thin layer of well-bonded rust or mill scale is usually acceptable. The inspection should insure that any material that will impair bond to the concrete for reinforcement is removed, such as paint, oil, grease, dried mud, and weak dried mortar.

Inspections should occur throughout reinforcement placement to avoid costly mistakes. The types and sizes of reinforcing bars and their locations need to be

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verified prior to concrete placement. Typically, the specifications contain criteria for spacing tolerances, which needs to be verified during inspection. Proper reinforcement grade, size, bending, spacing, location, splice length, and surface condition (cleanliness, temperature, amount of rust, etc.) should be checked and approved or rejected as appropriate.

In addition, the inspector needs to ensure that the reinforcement is positioned accurately in the forms and held firmly in place so that it does not move during concrete placement. Numerous methods are available to hold reinforcement in place, including concrete blocks, metallic and plastic supports, spacer bars, and wires. Metallic supports should not be used in contact with soil. Rocks, wood blocks, and similar supports not expressly made to support reinforcement should not be used.

Inspections need to verify the correct location of any embedded items to be in the cast-in-place concrete, such as waterstop, conduits, piping, and anchor bolts. Embedded items need to be securely fixed in place before concrete is placed and be held in position until concrete placements are finished. Typically, embedded items should not affect the positioning of reinforcement, unless specifically allowed in the specifications.

### **1. Joints**

Joints are installed in concrete structures to facilitate construction, to reduce shrinkage stresses, to control the locations of cracking, to allow for volumetric shrinkage or for expansion between sections of the structure, and to aid in the building of forms and the placing of concrete and reinforcement. The location of joints is critical for proper construction and long-term durability of the structure. The inspector needs to verify the location and type of each joint to confirm that they conform to the specifications.

#### **a. Construction Joints**

Construction joints are joints purposely placed in concrete to facilitate construction, to reduce initial shrinkage stresses and cracks, to allow time for installation of embedded items, or to allow for subsequent placing of other concrete. Bond of concrete across construction joints is required regardless of whether or not reinforcement is continuous across the joint. The specifications will dictate surface preparation requirements, including cleanliness and roughness, prior to placement of concrete against the joint, which the inspector needs to verify. Construction joints should be located as shown on the specification drawings or as approved by the design engineer. Mortar layers are not allowed at construction joints.

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### b. Control Joints

Control joints are joints placed in concrete to provide for control of initial shrinkage stresses and cracks in monolithic units. Reinforcement is continuous across control joints and there is no bond between the concrete surfaces forming the joint. In some cases, control joints can be created by sawcutting at the joint location. ACI 224.3 R<sup>8</sup> refers to these as contraction joints.

- **Sawcut control joints.**—Sawcut joints are a type of control joint that is typically used for slabs. The sawcuts should be completed within 24 hours following concrete placement and are required to be at least 1/4 of the depth of the concrete unless otherwise indicated on the specification drawings. The joints are straight, have sharp edges, and cut to the minimum width possible.
- **Cast control joint.**—In other cases, when sawcutting is not possible due to slab thickness or the presence of reinforcing steel, control joints are constructed by placing concrete on one side of the joint and allowing it to set before concrete is placed on the other side of joint. The surface of the concrete first placed at a control joint is coated with a curing compound, or similar bond breaker that prevents bond before placing concrete on the other side of the joint. The inspector needs to verify that the control joints are properly located and prepared.

### c. Partial Contraction Joints

Partial contraction joints are joints where no bond exists between concrete surfaces forming the joint and half of the reinforcement is continuous across the joint. They are constructed by placing concrete on one side of the joint and allowing it to set before concrete is placed on other side of joint. The surface of the concrete first placed is coated with curing compound, or a similar bond breaker, that prevents bond before placing concrete on the other side of joint. For these joints, only every other reinforcement bar perpendicular to the joint; i.e. half of the perpendicular reinforcement, crosses the joint. The discontinued bars should end 2 inches from the face of the joint.

### d. Contraction Joints

Contraction joints are joints placed in concrete to provide for volumetric shrinkage of a monolithic unit or movement between monolithic units, with no bond between concrete surfaces forming the joint and no reinforcement continuous across the joint. Contraction joints are constructed by placing concrete on one side of the joint, allowing it to set before concrete is placed on the

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<sup>8</sup> ACI 224.3 R “Joints in Concrete Construction (Reapproved 2013),” American Concrete Institute.

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other side of the joint. The surface of concrete first placed at a contraction joint is coated with curing compound or similar bond breaker before placing concrete on the other side of the joint. Typically, the only reinforcement that may cross the joint is smooth dowels

### **e. Expansion Joints**

Expansion joints are to allow for expansive movement of concrete elements. They usually contain some type of compressible joint filler that is adhered to one side of the joint.

In addition, Reclamation specifications typically do not allow preformed joints consisting of plastic or metal strips.

### **f. Joint QA**

Inspection needs to ensure that all joints are located and constructed as shown in the specifications or as approved by the design engineer. Changing concrete mixture proportions near the joints should not be allowed, and inspectors need to ensure that concrete near joints is properly consolidated. For joints formed by casting new concrete against existing concrete, all dirt, debris, oil, grease and any other foreign materials should be removed prior to application of a bond breaker if one is specified. However, care should be used to ensure surfaces of existing concrete are not damaged during joint preparation.

## **B. Quality Testing**

An issue that comes up on some projects concerns quality testing of concrete and which party (the contractor or Reclamation) will perform testing that will be used to determine acceptability of work (QA). Primary responsibility for quality testing for acceptance is usually one of the following cases. They are listed in order of preference:

- Government personnel perform full QA testing
- Government retains an independent testing agency to perform full QA testing
- Contractor is required to retain an independent testing agency to perform testing

The recommended practice for Reclamation is to have Government personnel perform full QA testing of concrete. When Government personnel will not be performing full QA testing of concrete, one option is for the Government to

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contract with a testing agency to perform that testing. The specifications would be the same for these two situations. Testing agency personnel would be acting on behalf of the Government when performing tests, so the relationship to the construction Contactor would be the same as if Government personnel were performing the tests. In this case, the contractor is usually not required to hire an independent testing agency for quality testing. If a private firm is used by the Government, it must not be affiliated with the contractor.

If the Government will not be performing full QA and plans on using the contractor test results to determine acceptability of work (the least preferred method, as discussed earlier), then the contractor will be required to retain a qualified independent testing agency to perform the quality testing. In this case, the Contractor Quality Testing article needs to be included in the concrete specification. See section E – Contractor Quality Testing below.

If the Government will be conducting full QA testing, then the Government will perform, as a minimum, the tests listed in Table 1 – Batch Plant Testing and Table 2 – Field Testing. Typical QA testing requirements are described in more detail in Section VI– Inspection and Testing Requirements, below. This testing is in addition to the contractor’s QC program and does not relieve the contractor of performing adequate QC testing. The list of tests is sometimes provided in the specifications to alert the contractor to potential impacts to work scheduling. The Government testing frequency is at the discretion of the Contracting Officer’s Representative (COR). Greater frequency testing is normally performed at the start of placing a mix design, when changing a mix design, when inconsistencies of materials are noticed, in critical portions of the structure, or when significant changes are made at the batch plant. The tests and testing frequency listed in the tables are provided only as approximation of Government testing. The COR should be notified immediately of test results showing that materials do not meet specifications. When test results show materials meet specifications, the COR should be notified within two hours.

Table 1.—Batch Plant Testing

Tests of	Test Standard	Standard Title	Requirement	Testing Frequency
Aggregate Gradation	ASTM C136 <sup>9</sup>	Sieve Analysis of Fine and Coarse Aggregates	Fine and Coarse Aggregate meets sizing requirements per ASTM C33 <sup>10</sup> .	At beginning of placing each mix. At change in mix design. At least every 500 yd <sup>3</sup> of placing a mix.

<sup>9</sup> ASTM C 136, “Sieve Analysis of Fine and Coarse Aggregates,” American Society for Testing and Materials (ASTM) International.

<sup>10</sup> ASTM C 33, “Concrete Aggregates,” ASTM International.

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Tests of	Test Standard	Standard Title	Requirement	Testing Frequency
Aggregate Fines Content	ASTM C117 <sup>11</sup>	Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing	Fine aggregate meet specified allowable fines content (material passing No. 200 sieve)	At beginning of placing each mix. At change in mix design. At least every 500 yd <sup>3</sup> of placing a mix.
Aggregate Moisture Content	ASTM C566 <sup>12</sup>	Total Evaporable Moisture Content of Aggregate by Drying	Verify that moisture meter at batch plant is accurate with the material batched.	At beginning of placing each mix. At change in mix design. At least every 500 yd <sup>3</sup> of placing a mix.

Table 2.—Field Testing

Tests of	Test Standard	Standard Title	Testing Frequency
Fresh Concrete Properties – tests performed at site	ASTM C 143 <sup>13</sup>	Slump of Hydraulic-Cement Concrete	1 set of tests per load for first two loads.
	ASTM C 231 <sup>14</sup>	Air Content of Freshly Mixed Concrete by the Pressure Method (alternative to ASTM C 138 gravimetric method)	When tested concrete meets specifications, 1 set of tests each day of placement for each mixture for the first 50 or less cubic yards, and 1 set of tests for each additional 100 cubic yards of concrete. Minimum of 1 set of tests per hour during placements.
	ASTM C 1064 <sup>15</sup>	Temperature of Freshly Mixed Hydraulic-Cement Concrete	
	ASTM C 138 <sup>16</sup>	Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete	When concrete does not meet specifications, test each load until 2 consecutive loads meet specifications, then resume testing frequency specified above.

<sup>11</sup> ASTM C 117, “Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing,” ASTM International.

<sup>12</sup> ASTM C 566, “Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying,” ASTM International.

<sup>13</sup> ASTM C 143, “Slump of Hydraulic-Cement Concrete” ASTM International.

<sup>14</sup> ASTM C 231, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method” ASTM International.

<sup>15</sup> ASTM C1064, “Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete,” ASTM International.

<sup>16</sup> ASTM C 138, “Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete,” ASTM International.

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Table 2.—Field Testing

Tests of	Test Standard	Standard Title	Testing Frequency
Compressive Strength	ASTM C 31 <sup>17</sup>  ASTM C 39 <sup>18</sup>	Making and Curing Concrete Test Specimens in the Field  Compressive Strength of Cylindrical Concrete Specimens	1 set of samples (6"x12") for each day of placement for each mixture for the first 50 or less cubic yards, and 1 set of samples for each additional 100 cubic yards of concrete. A minimum of 5 samples for strength testing shall be made each time strength samples are collected.  2 additional field cured test cylinders during placement in adverse (hot or cold) weather. Cure these samples on jobsite under the same conditions as the concrete the cylinders represent for a minimum of 7 days, then transfer to the testing laboratory until testing at strength design days.  Test 2 cylinders each at 7 days age and 2 cylinders at strength design age. Maintain the last cylinder for testing in the event that the strength design age test results fall below the required strength.
Concrete Cores	ASTM C 42 <sup>19</sup>	Obtaining and Testing Drilled Cores and Sawed Beams of Concrete	At discretion of the Government when cylinder strengths fail to meet minimum requirements.  The contractor shall obtain core specimens in accordance with ASTM C42 at locations directed by COR, at no additional cost to the Government. The contractor shall repair the core holes in accordance with Reclamation M-47 or as directed by COR

Finally, reporting requirements should be developed. Reports can be generated for monthly documentation and evaluation of concrete tests performed by Reclamation QA staff or independent QA laboratories. A final construction report should be maintained as a record for future evaluations. Comparing historical records to present performance provides an excellent means of evaluating structures during facility reviews.

<sup>17</sup> ASTM C 31 “Standard Practice for Making and Curing Concrete Test Specimens in the Field,” ASTM International.

<sup>18</sup> ASTM C 39 “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens,” ASTM International.

<sup>19</sup> ASTM C 42, “Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete,” ASTM International.

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### C. Quality Control

The contractor is responsible for QC to the extent required to deliver the services or supplies in accordance with the contract requirements. QC includes a system to manage, control, and document work to ensure compliance with the contract requirements. The contractor's responsibility includes ensuring adequate QC services are provided for work accomplished on and off-site by the contractor's own organization, suppliers, manufacturers, subcontractors, technical laboratories, and consultants. The work activities include safety, submittal management, and all other functions relating to the requirements.

The contractor is required to comply with all requirements of FAR 52.246-12 – Inspection of Construction.<sup>3</sup> According to the FAR, “The contractor shall maintain an adequate inspection system and perform such inspections as will ensure that the work performed under the contract conforms to contract requirements. The contractor shall maintain complete inspection records and make them available to the Government. All work shall be conducted under the general direction of the COR and is subject to Government inspection and test at all places and at all reasonable times before acceptance to ensure strict compliance with the terms of the contract.”

The FAR goes on to say, “The Contractor shall promptly furnish, at no increase in contract price, all facilities, labor, and material reasonably needed for performing such safe and convenient inspections and tests as may be required by the Contracting Officer. The Government may charge to the Contractor any additional cost of inspection or test when work is not ready at the time specified by the Contractor for inspection or test, or when prior rejection makes reinspection or retest necessary.”

Except for tests or other items of work specified to be performed by the Government, work quality shall be the responsibility of the contractor. The contractor is responsible to inspect work and test often enough or as specified in the contract documents to ensure that quality materials, workmanship, construction, finish, and functional performance is in compliance with applicable specifications and drawings. The contractor is required to submit a QC plan in accordance with Reclamation's Specifications, Sections 01 46 00 – Quality Procedures<sup>20</sup> and 01 46 20 – Testing Agency Services,<sup>20</sup> for approval, and shall make available all required testing and inspection reports to the Government.

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<sup>20</sup> Bureau of Reclamation, “Guide Specifications and Standard Drawings.”

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### **D. Quality Submittals by the Contractor**

In many specifications, the contractor is required to submit for approval the contractor's overall plan for QC and Contractor Quality Testing. It will include plans, methods, procedures, sequences, and scheduling for conducting QC and Contractor Quality Testing. Separate and more detailed submittals may be required for the main definable features.

### **E. Contractor Quality Testing**

Contractor quality testing refers to tests required by the specifications to be performed and recorded by the contractor that may be used for Government QA. Generally, Reclamation does not specify details of the contractor's QC. However, the Contractor Quality Testing article can be included when requested by the inspection office.

When Government personnel or when Government retained testing agency personnel will be performing QA testing, the Contractor Quality Testing Article can be deleted. At a minimum, any of the tests specified in the Quality Testing article should be part of the contractor's inspection program. In this situation, the contractor would generally not be required to retain an independent testing agency to perform concrete quality tests. Contractor Quality Tests could be performed by qualified contractor or batch plant personnel.

When editing the Contractor Quality Testing and QA articles in a new concrete specification section, the specification author should be aware of how the office responsible for field inspection plans to have quality testing of concrete performed. This would best be accomplished by contacting that office.

As discussed earlier, having a testing agency hired by the contractor to perform tests that are anticipated to be used for acceptance is the least desirable option. When the inspection office plans to use contractor performed testing in lieu of Government QA testing for acceptance of work (i.e. Government personnel or Government retained testing agency personnel will not perform full QA testing of concrete), the contractor should be required to retain an independent testing agency to perform quality testing of concrete. When an independent testing agency is specified, include Section 01 46 20 – Testing Agency Services<sup>20</sup> in the specifications. Include Cast-In-Place Concrete in the list of sections requiring testing in Reclamation's Specifications, Section 01 46 20. Government contract personnel need to be aware that there is added risk of false reporting when the contractor pays the testing agency that is performing tests that are anticipated to be used for acceptance.

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If the Government will do little or no QA testing and the contractor is required to obtain an independent testing agency to perform tests that the Government anticipates using for determining acceptability of work, then in addition to specified Contractor Quality Testing, the Government still has the option of performing tests listed in Table 1 and Table 2.

Testing must conform to the requirements of the referenced American Society for Testing and Materials (ASTM), Reclamation, or other referenced industry standards, and must be performed by qualified personnel. The contractor may use these tests as part of the contractor QC program. In addition, the quality testing specified in the Contractor Quality Testing article do not relieve the contractor from performing QC testing and verification as needed to ensure delivery of a product meeting specification requirements. The Government may also choose to use Contractor Quality Testing results for QA if deemed necessary by the COR.

### **1. Contractor Batch Plant Quality Testing**

If the Government will not be performing QA testing, and the contractor or independent testing agency will be performing quality testing, the sampling, testing, and reporting for batch plants should be performed as shown in Table 1. The testing frequencies should be adjusted as appropriate for each job. Personnel conducting tests should be qualified as an ACI Aggregate Testing Technician, Level 1, or equal. The COR should be notified immediately of test results showing failure of materials to meet specifications. Passing test results should be submitted in a report to the COR within 24 hours, submitting the test results as shown in Table 1.

### **2. Contractor Field Quality Testing**

If the Government will not be performing QA testing, and the contractor or independent testing agency will be performing quality testing, then the sampling, testing, and reporting for field quality testing should be performed as shown in Table 2. The testing frequencies should be adjusted as appropriate for each job. Personnel conducting plastic concrete field tests should be qualified as ACI Concrete Field Testing Technician, Grade 1, or equal. Personnel conducting concrete specimen tests should be qualified as ACI Concrete Strength Testing Technician, or equal. The COR should be notified immediately of test results showing that materials do not meet specifications. When test results show materials meet specifications, the COR should be notified within 24 hours.

The concrete section of the specification will list the applicable standards for acceptance of test results. For example, the acceptance criteria for a compressive

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strength test are in accordance with ASTM C94,<sup>21</sup> except that for many concrete mixtures, 90 percent of test cylinders should exceed the specified compressive strength at the design age (mass concrete may be 80 percent<sup>22</sup>). In addition, the average compressive strength of any six consecutive test cylinders should exceed the specified compressive strength at the design age. No individual strength test should be below the specified compressive strength by more than 500 lb/in<sup>2</sup>.

If drilled cores are used for acceptance of concrete, core tests will be considered structurally adequate when the average compressive strength of three cores is equal to at least 85 percent of the specified compressive strength and no single core has a compressive strength of less than 75 percent of the specified compressive strength. Concrete in placement represented by core tests will be considered adequate for durability when the average compressive strength of three cores is equal to at least 100 percent of specified compressive strength at the design age.

### III. Quality Related References

The QMP should contain a section that lists all the specification references related to quality. An example is below.

#### **ASTM International**

- |               |  |
|---------------|--|
| ASTM C 1077   | Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation |
| ASTM E 329    | Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction                                  |
| ASTM E 543-06 | Evaluating Agencies that Perform Nondestructive Testing  |

#### **Bureau of Reclamation (Reclamation)**

- |                |  |
|----------------|--|
| Reclamation CM | Concrete Manual, Eighth Edition, Revised Reprint, 1981 |
|----------------|--|

#### **International Code Council**

- |          |   |
|----------|---|
| IBC 2012 | International Building Code. International Code Council, Inc., 2012. <sup>1</sup> |
|----------|---|

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<sup>21</sup> ASTM C 94 “Standard Specifications for Ready-Mixed Concrete.” ASTM International.

<sup>22</sup> Concrete Manual, Eight Edition Revised, US Department of the Interior, Bureau of Reclamation, 1981.

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### IV. Personnel Requirements

#### A. Reclamation Concrete Materials Design Team Member Requirements

The concrete materials design team member (CDTM) is responsible for ensuring sufficient involvement in the project throughout construction and operation of the project. The CDTM may need to interpret certain issues with the specifications and ensure that the design intent is adequately portrayed and understood by the field construction staff.

The CDTM is responsible for the review and comment/approval of submittals for concrete and concrete making materials, and to formally provide a response to the contracting officer or his representative within the allotted time period. For most Reclamation concrete projects the specification identifies concrete requirements (for example strength, air content, and slump). The contractor then submits mix design information such as the materials used, proportions, strength data, and describes how the concrete will be produced to meet specification requirements. Once the concrete submittal is approved, the concrete must be proportioned within the tolerances specified in the contract, which are typically the tolerance requirements shown in ASTM C 94<sup>21</sup>. For example, the mass of the cement must fall within +/- 1 percent of the approved mass, if the quantity of cementitious materials exceeds 30 percent of the full capacity of the scale. Concrete that is produced, but has ingredient quantities that do not meet the specified tolerances, should be rejected. Some projects will require several different classes of concrete. A separate submittal is required for each mixture and any change in ingredients usually requires re-submittal. Any concrete design changes initiated during submittal reviews must be done in conjunction with the COR or his representative.

The COR is usually in charge of coordination and communication with the CDTM on concrete related activities, QC and QA test results, and should bring unusual conditions and circumstances to the designers' attention. The CDTM should be available and responsive to the resident engineer's needs during construction operations and approve of changes to the concrete design or technical requirements of the specifications.

It may also be necessary for the CDTM to coordinate with the COR for site visits during construction to verify that site conditions are as assumed in the design, and to verify concrete mixing, construction methods and practices are achieving the intent of the design. The CDTM may be called on to determine and make recommendations to the COR when design changes or mixing procedures are needed to suit the actual conditions, and assist the COR in arriving at concrete

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proportioning and construction methods that will meet the design intent if conditions vary from those assumed during design. Initial and periodic batch plant inspections may also be appropriate.

### **B. Reclamation QA Personnel Requirements**

For many jobs, the anticipated personnel and specific roles and responsibilities related to quality should be listed in a Roles and Responsibilities section of the QMP.

The effectiveness of QA is largely dependent on the abilities of the QA staff (inspectors and laboratory staff). The representative(s) must be properly educated and certified and have sufficient experience to correctly perform the required inspections and acceptance tests.

Plans for providing QA staff need to be developed prior to the start of construction. The skill of the staff (for example, certification requirements) also needs to be defined early on. For some jobs it may be appropriate to provide construction inspection and materials testing coverage for all shifts of the contractor's work performed under the project. The plan may require that experienced, trained and certified construction inspectors, and materials technicians are needed to meet Reclamation's responsibilities in performance of QA. The plan should also delineate requirements for supervisory staff and who is ultimately responsible for QA. For example, the plan might designate a professional engineer be employed full-time at the project site to supervise QA activities and the COR can be designated to be responsible for the QMP implementation and performance.

The size of the concrete placement should not be the controlling factor when accessing the need for QA staff. Rather, the criticality of the placement and the consequences of poor quality should be assessed when determining the level of effort needed for QA.

#### **1. Reclamation Construction Laboratory (Field Laboratory)**

The Government field laboratory should meet ASTM specifications for agencies engaged in testing and inspection and Reclamation requirements for equipment type and inventory, calibration, and use. The laboratory must calibrate measuring devices, laboratory equipment, and instruments at established intervals against certified standards in accordance with ASTM and Reclamation requirements. A laboratory QA document should be created by the local area or regional office in accordance ASTM and other industry standards.

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The laboratory needs to keep records of equipment inventory, equipment calibrations dates, a complete library of test procedures, personnel qualifications, and test report forms. Test results should be entered into an electronic record keeping system or other Reclamation field-testing database systems, as necessary. Results should be summarized monthly in an L-29 – Construction Progress Report.

Third party independent testing laboratories employed by the Government or the contractor must be certified to perform the type of sampling and testing for which they are engaged and meet the requirements above, and the ASTM specifications for laboratories for the types of services provided. All independent laboratories need to supply Reclamation copies of all administered tests in a timely manner after the test is performed, generally within 1-2 days of completion of the test.

Reclamation project field laboratory staffing for large concrete projects should include a concrete materials expert (lab chief) reporting to the engineer responsible for all phases of QA from aggregate production through curing and protection of the concrete. A supervisor in charge of materials testing should be available for each shift. Under each supervisor, there should be enough personnel to adequately perform all required QA testing such as acceptance testing of aggregates and concrete, to prepare reports, prepare summary reports, and keep records. Staffing needs to be adequate to perform all required tests to established standards as defined and required in the specification for the purposes of verifying the contractor's work is achieving minimum results for acceptance by the COR.

The lab chief, in coordination with the COR, will develop a materials testing plan that will meet the contractor's schedules. Materials testing should be conducted at the construction site whenever possible.

The lab chief should consult Reclamation's Technical Service Center Concrete Materials Lab when questions arise or further guidance is necessary for performing the tests. If additional resources outside of Reclamation are needed, the materials lab may contract with an independent testing laboratory that meets the applicable standards and specifications.

The lab chief needs to ensure that materials testing equipment and procedures meet all applicable standards and personnel and equipment certifications are current. The COR needs to be advised if issues or problems develop within the lab. Lab practices should meet Reclamation Safety and Health Standards (RSHS) and Job Hazard Analysis (JHA) developed and reviewed with technicians prior to start of new testing procedures.

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The lab chief should keep the COR advised of the resources required to meet contractor schedules and testing requirements. Lab technicians should be trained and proficient in the operation of lab equipment and should be capable of performing all required tests to establish procedures and standards. Technicians usually work closely with Reclamation inspectors in the field and coordinate the testing to meet the safety requirements set by the contractor.

For smaller projects, the size of the QA staff can be modified to suit the project conditions. In most instances, QA staff is required to serve in several capacities, shifting from quality verification of concrete mixing and placing to other phases of the work, including inspection. QA staff may also be required to verify curing, protection, and cleanup. It is best to have continuous quality verification of batching and mixing operations.

For ready-mix operations, when concrete is centrally mixed at a plant, a member of the QA staff should be on duty at the concrete batch plant so that plant operations can be observed and the mixed concrete can be tested and possibly rejected when a concrete batch fails to meet job requirements. When concrete is transit-mixed, full-time plant quality verification is desirable, but primary responsibility for acceptance of concrete belongs to QA staff at the site of the work. If full-time plant QA is not possible, the plant should be inspected frequently to ensure that batching is carried out properly. For these operations, it is common to require that ready-mix plants have a current National Ready Mix Concrete Association Certification of Production Facilities, which includes automatic digital recording of cementitious materials, aggregate, water, and chemical admixtures.

## **2. *Reclamation Construction Inspection***

Thorough inspection is critical to the success of a quality project. Under the supervision of the COR, the inspector performs daily inspection duties at assigned areas of construction being performed by the contractor. Prior to the inspection, the inspector should read and understand the specification requirements and confirm that the contractor's means and methods will provide results meeting the specifications. Any questions should be directed to the resident engineer, lead inspector, or materials testing lab chief.

Inspectors should issue a daily report at the close of their shift and these reports should be reviewed by the lead inspector daily. Inspectors must note and record all the details of the contractor's construction efforts. These reports should cover all-important factors affecting the condition and the progress of the work, and any instructions or conversations with the contractor. The reports should include

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facts, not opinions, and include data on tests made, samples taken, photographs, and other applicable test data.

Daily report forms should be selected prior to the start of work. Regional or area offices may have their own guidelines for these forms and they should be consulted. These daily inspection report forms should be modified as necessary depending on the construction activity. Inspectors must also photograph work conditions, work progress, critical issues, and safety deficiencies. An accurate log and description of the photographs should also be maintained. Official photographs should be created and maintained in accordance with established project guidelines<sup>23</sup> and Reclamation regional policies.

Inspectors need to review the contractors' operations for quality of work and compliance with approved JHA and RSHA. Any construction issues, unacceptable work, defective material, and any safety issues should be reported to the lead inspector. If repeat safety violations become common occurrence, the lead inspector and resident engineer should be informed about the situation so corrective actions can be taken. Recommending a work stoppage, effective immediately, may be necessary. Notify the contractor immediately if operations are not being performed properly. If the contractor does not correct operations, use quality test results or quality procedures established by the project or resident engineer to provide a basis to reject the contractor's work.

The inspector should coordinate with the contractor and Reclamation materials laboratory QA staff for scheduling QA testing throughout the project, and should keep the contractor informed of test results. A statistical review of test results should be performed to ensure that the overall product requirements are met or exceeded.

Inspection can identify problem areas for QA and QC testing. QA testing should be used to calibrate observations. Inspectors should direct QA testing operations to areas where non-compliant specification requirements are suspect or are obvious in nature.

All inspection reports become an important part of the permanent record of the project. If questions about the construction arise at a later date these reports become important reference documents. It is important to keep track of both people and equipment for possible contractor payment disputes.

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<sup>23</sup> Bureau of Reclamation, Information Management, "Volume 4 – Photographic Media Management," <http://intra.usbr.gov/records/Vol%20IV/photomanual.pdf>.

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### **C. QA/QC Coordination Meetings**

Regular coordination meetings with the contractor (and subcontractors) should be scheduled and attended by all necessary Reclamation personnel to discuss project schedule, construction activities, submittal status, requests-for-information, problems, and solutions.

Prior to the start of work for each definable work item, a pre-construction meeting is recommended to review and address Reclamation's and the contractor's QA/QC roles, responsibilities, and testing and inspection frequencies for the specific work. Attendance by the Reclamation COR and appropriate personnel, the contractor's QC manager and responsible construction superintendent, and the foreman responsible for the type of work is recommended to review the applicable specification sections and contract drawings, verify that appropriate shop drawings and submittals for materials and equipment have been submitted and approved, and review the testing plan and QA/QC requirements.

These meeting should also be viewed as a venue to circumvent potential problems and an opportunity to discuss the resolution of issues in an attempt to increase the efficiency of both organizations.

### **D. Contractor QC Personnel Requirements**

The specific requirements for the contractor QC will depend on the size of the job and the type of specification. A more performance-based specification will mean the contractor will need more and perhaps better QC staff. A more prescriptive specification may mean the contractor can use a smaller QC staff. Depending on the size of the job, the contractor may designate a QC manager to be employed full time at the project site to manage the contractor's quality program in accordance with the specifications and the FAR. The QC manager should have sufficient experience according to the size of the job and it may be appropriate to require the QC manager be a licensed professional engineer or have relevant current ACI certifications.

The contractor should submit a QC testing plan, and include the resume of the QC manager and list certifications of the QC personnel with proof of required ACI certifications or independent laboratories, per the specifications. QC duties may be performed by the contractor or the contractor's independent testing laboratory. The Government will review and approve the contractor's QC testing plan. Personnel including independent laboratories contracted by the contractor must be certified to perform sampling and testing and meet the applicable ASTM requirements for the services to be performed.

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Personnel conducting plastic concrete field tests should be qualified as an ACI concrete field testing technician, at a grade 1 or equal. Personnel conducting concrete specimen tests should be qualified as an ACI concrete strength testing technician, or equal.

Contractor personnel may need one or more of the following certifications:

- ACI aggregate testing technician
- ACI concrete flatwork finisher
- ACI concrete field testing technician
- ACI concrete strength testing technician

When the contractor is placing concrete it should be performed under the direct supervision of a certified ACI concrete flatwork finisher. The specification should list each placement requiring ACI concrete flatwork finisher supervision. ACI concrete flatwork finisher certification requires passing a written test, successfully completing a performance examination, and possessing actual on-the-job finishing experience (performance test plus 1,500 hours experience), or possessing a higher level of actual on-the-job experience (4,500 hours experience). ACI also has certification for a concrete flatwork technician. This certification does not require on-the-job finishing experience and is not recommended for a supervisory role, unless the supervisor has sufficient construction experience.

## V. Material Requirements

### A. Strength and Durability Requirements

#### 1. Strength Requirements

The ACI Building Code<sup>1</sup> includes requirements for qualification of the concrete mixture based on strength and durability and minimum requirements for quality assurance testing. The concrete mixture strength requirement has two primary criteria based on the design strength ( $f'_c$ ):

1. The required average strength ( $f'_{cr}$ ) is appreciably higher than the design strength ( $f'_c$ ) to ensure that 90 percent of all tests **exceed** the design strength (or a 1 percent chance that any three consecutive tests fall below  $f'_c$ ), and
2. No test (average of two cylinders) should fall below the design strength by more than 500 pounds per square inch (psi).

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Past test data is used to determine the over-design needed to meet these requirements. The required average strength ( $f'_{cr}$ ) is based on statistical criteria and depends on the variability of test results of the mixture in question. The maximum water to cementitious materials ratio (w/cm ratio) for the design mixture is then selected to meet the required average strength. Thirty strength test results over a 24-month period are required to demonstrate the quality of the production facility for each mixture. If there are fewer than 30 tests, or if there are no test results the ACI Building Code<sup>1</sup> requires additional over-design factors. For example, a typical concrete mixture with a design strength of 4,500 lb/in<sup>2</sup> and average quality will require an average strength of about 5,170 lb/in<sup>2</sup> if 30 test results are available and about 5,700 lb/in<sup>2</sup> if no test data are available. The Code also provides procedures for qualifying a concrete mixture based on testing trial batches of concrete with the selected materials.

**2. Durability Requirements**

The ACI Building Code<sup>1</sup> also requires compliance with minimum durability requirements. This includes criteria for freezing and thawing (F/T) environments, sulfate environments, water exposure, and corrosion protection of reinforcement. It is the designer of record’s responsibility to classify the site for durability and must pick an exposure class for F/T, sulfate, water, or corrosion according to ACI 318-14<sup>1</sup>. The durability criteria for F/T include specifying a maximum W/(C+P) ratio, minimum strength, and appropriate entrained-air content. Requirements for sulfate resistance include a maximum W/(C+P) ratio, minimum compressive strength, and cement type, based on the severity of the sulfate exposure. Durability requirements often govern over strength requirements in many Reclamation structures due to the service conditions and nature of exposure in western and mountain environments. Reclamation also requires the materials used for concrete (cement, pozzolan, aggregates, and admixtures) meet quality requirements according to ASTM specifications to ensure durability. Table 3 shows an example checklist for documenting concrete making materials.

Table 3.—Example Checklist for Documenting Concrete Materials

Fine aggregate	ASTM C 33 <sup>10</sup>	Physical properties	
		Grading	
		Freeze-thaw durability	
	ASTM C 295 <sup>24</sup>	Petrographic examination alkali-silica reactivity	

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<sup>24</sup> ASTM C 295, “Standard Guide for Petrographic Examination of Aggregates for Concrete.” ASTM International.

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Coarse aggregate	ASTM C 33 <sup>10</sup>	Physical Properties	
		Maximum size	
		Grading	
		Freeze-thaw durability	
	ASTM C 295 <sup>24</sup>	Petrographic examination alkali-silica reactivity	
Cement	ASTM C 150 <sup>25</sup>	Type	
		Sulfate resistance	
		Low alkali limitation	
		Chemical/physical requirements	
Pozzolan	ASTM C 618 <sup>26</sup>	Class (N, F, C)	
		“R factor”	2.5 maximum
		Chemical/physical requirements	
Admixtures – air entraining	ASTM C 260 <sup>27</sup>		
Admixtures – chemical	ASTM C 494 <sup>28</sup> ASTM C 1017 <sup>29</sup>		
Admixtures – other	ASTM 494 <sup>28</sup>		

**3. Procedures for Evaluation of the Starting Concrete Mixture**

A number of important decision steps should be followed to assure the mix and materials meet both the strength and durability requirements for concrete. The following outline shows the necessary requirements that should be followed to comply with the ACI Building Code<sup>1</sup> and/or Reclamation requirements for durable concrete construction. Some of the requirements only need to be documented for initial use of a concrete materials supplier, such as documentation of materials used. Others should be documented for compliance with the ACI Building Code<sup>1</sup> on a daily or routine basis.

<sup>25</sup> ASTM C 150 “Standard Specification for Portland Cement,” ASTM International.

<sup>26</sup> ASTM C 618 “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete,” ASTM International.

<sup>27</sup> ASTM C 260, “Standard Specification for Air-Entraining Admixtures for Concrete,” ASTM International.

<sup>28</sup> ASTM C 494 “Standard Specification for Chemical Admixtures for Concrete,” ASTM International.

<sup>29</sup> ASTM C 1017 “Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete,” ASTM International.

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<p>1. Design Strength _____</p> <p>a. Percent required to exceed design strength (usually 90 percent) _____</p> <p>b. Coefficient of variation or standard deviation of mix based on 30 tests (or with adjustment for 15 to 30 tests – ACI 301 Table 4.2.3.3.a.1 <sup>1/</sup>) _____</p> <p>c. Required average compressive strength</p> <p style="padding-left: 20px;">i. Based on 15 to 30 tests _____</p> <p style="padding-left: 20px;">ii. If less than 15 tests are available – use required average strength based on ACI 318 Table 5.3.2.2 (typically the design strength plus 1,200 lb/in<sup>2</sup>) _____</p> <p>d. W/(C+P) ratio required for strength _____</p> <p>e. W/(C+P) ratio required for durability _____</p> <p>f. W/(C+P) ratio selected for the mix (use lowest of 5 or 6) _____</p> <p><small><sup>1/</sup> ACI 301-10 “Specification for Structural Concrete”</small></p>
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Figure 1.—Example mix design requirement – strength and durability criteria.

Table 4.—Example Checklist for Concrete Mixture Proportions

	Example Requirement <sup>A</sup>	Actual Required
<b>Design compressive strength</b>	4,000 lb/in <sup>2</sup>	
Test age	28 days	
Percent of tests exceeding design strength	Structural (S) – 90 Mass (M) – 80	
Standard deviation or coefficient of variation	15 percent	
<b>Average compressive strength required</b>	S – 4,980 lb/in <sup>2</sup> M – 4,590 lb/in <sup>2</sup>	
w/cm ratio for strength (based on site materials used)	0.44	
w/cm ratio for durability – freeze-thaw <sup>B</sup>	Chose ratio according to exposure class	
w/cm ratio for Durability – Sulfate <sup>B</sup>	Chose ratio according to exposure class	
w/cm ratio for durability – water exposure <sup>B</sup>	Chose ratio according to exposure class	
w/cm ratio for durability – corrosion <sup>B</sup>	Chose ratio according to exposure class	
w/cm ratio required <sup>C</sup>	0.44	
Maximum size aggregate	3/4 inch 1-1/2 inch	
Air content	3/4 – 6 percent 1-1/2 – 5 percent	
Percent pozzolan	15 percent	

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	Example Requirement <sup>A</sup>	Actual Required
Slump	3 inches	
Ready mix concrete	ASTM C 94 <sup>21</sup>	

<sup>A</sup> The values listed are based on typical structural concrete requirements and normal QC practices (no durability increase). The actual values should be determined for each class of concrete.

<sup>B</sup> Exposure class<sup>5</sup>.

<sup>C</sup> The lowest of the W/(C+P) ratios for strength and durability should be chosen.

## B. Requirements for Documentation of Concrete Mix Design

### 1. Example Requirements for Materials

1. Aggregates:
  - a. Certification meeting ASTM C 33<sup>10</sup> physical properties
  - b. Certified test results of required ASTM grading for each material
  - c. Petrographic examination – physical quality examination and mineralogical identification of potentially reactive aggregates in accordance with ASTM C295.<sup>24</sup>
  - d. Quality
    - i. Alkali reactivity – performance tests for potential alkali reactivity
    - ii. Freezing and Thawing Durability in Concrete – performance in freezing and thawing tests
2. Cement:
  - a. Certification meeting ASTM C 150<sup>25</sup>
  - b. Type (I, II, V, etc.)
  - c. Potential for sulfate attack on project (specify sulfate resisting cement, Type II or V, and pozzolan, if necessary)
  - d. Potential for alkali-aggregate reactivity (use low-alkali cement, fly ash, slag, or lithium)
  - e. Optional chemical and physical requirements
3. Pozzolan: Recovered/recycled materials: Agencies that procure \$10,000 or more worth of cement and concrete, including concrete products, in one fiscal year are required by 40 CFR 247<sup>30</sup> to specify that such items contain coal fly ash (Class C or F) or ground granulated blast furnace slag (GGBFS). Exceptions are made only if fly ash is too costly, not readily available, or not suitable for performance requirements. Solicitations mandating use of fly ash must contain FAR clauses 52.223-4 – Recovered

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<sup>30</sup> 40 CFR 247 “Comprehensive Procurement Guideline for Products Containing Recovered Materials”, Code of Federal Regulations, 2002

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Material Certification and 52.223-8 – Estimate of Percentage of Recovered Material Content for EPA-Designated Products – Alternate I.”

- a. Certification meeting ASTM C 618<sup>26</sup>
  - b. Class (F or C)
  - c. Percent used in concrete
  - d. “R Factor” (indicator of sulfate resistance, maximum of 2.5)
4. Optional chemical requirements:
    - a. Available alkalis
  5. Optional physical requirements:
    - a. Strength activity index (7 and 28 days)
    - b. Effectiveness in controlling alkali-silica reaction
  6. Admixtures (including special admixtures) – identify manufacturer and conformance with applicable ASTM specifications:
    - a. Air-entraining admixtures – required for most construction
    - b. Water-reducing, set-controlling admixtures (WRA)
      - i. ASTM C 494<sup>28</sup> Type (A through G)
      - ii. Use non-chloride for accelerators
      - iii. Extended set-retarding admixture
      - iv. Superplasticizers (ASTM C 494<sup>28</sup> Type F and G, C 1017)

## VI. Inspection and Testing Requirements

### A. Quality Assurance Testing Requirements – Structural Concrete

The Code requires quality testing be performed to assure the concrete mixture meets the minimum strength and durability performance requirements. See the discussion earlier under Roles and Responsibilities about preferences for QA testing. Laboratories should follow a quality assurance program, use certified testing technicians, and be independent of the contractor. The testing should include fresh properties testing, strength testing, and documentation of the actual quantities of materials used in the concrete and the water to cementitious materials ratio. A test batch and testing during concrete production of the concrete mixture can be used to determine the actual quantities per cubic yard. The test batch requires records of the quantities batched and test samples of individual aggregate grading and moisture content.

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1. **Quality Assurance Testing – Minimum Requirements for Strength Testing (one set consists of 2 cylinders tested at indicated test age)**
  1. Not less than one set of strength tests *per Class* of concrete *per day*
  2. Minimum of one set of strength tests *per day* for:
    - a. Every 150 cubic yards of concrete
    - b. Every 5000 square feet of slabs
  3. Minimum of five randomly selected tests *per Class of concrete per project*
  4. Projects with a total volume of less than 50 cubic yards may be accepted based on evidence of satisfactory strength and approval by building official (Contracting Officer)
  
2. **Quality Assurance Testing – Typical Requirements and Reporting**
  1. Concrete Batch Plant
    - a. Pre-construction and periodic check requirements:
      - i. Documentation on aggregate sources and physical properties tests
      - ii. Documentation on cement and pozzolan
      - iii. Documentation on admixtures
      - iv. Documentation on scale calibration
    - b. Daily checks
      - i. Moisture content (sand and each size of coarse aggregate)
      - ii. Grading (amount retained on the No. 200 sieves from washing and sand and each size of coarse aggregate)
      - iii. Batch tickets for each load of concrete (including time batched and adjusted scale weights of ingredients)
  
  2. Fresh and Hardened Concrete Tests
    - a. Routine tests (performed on first concrete batched and periodically during placement)
      - i. Slump
      - ii. Temperature
      - iii. Density
      - iv. Percent air
    - b. Daily concrete test batch (typically one per class of concrete per day):
      - i. Slump
      - ii. Temperature
      - iii. Density

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- iv. Percent air
  - v. Yield summary of ingredients per cubic yard adjusted for grading and moisture
  - vi. w/cm ratio based on yield summary
  - vii. Casting test cylinders, appropriate for size of aggregate (typically cast two for testing at seven days, two for testing at 28 days, one spare, and two each for other strength-age requirements (90 or 180 days or one year)
3. Daily Report (typically reported for each class of concrete)
    - a. Structure identification and location
      - i. Source of concrete (contractor's plant, ready-mix supplier, etc.)
      - ii. Yield quantities and total cubic yards of concrete placed
      - iii. Cement and pozzolan quantities
  4. Monthly Report (typically for each class of concrete or each aggregate source)
    - a. Summary of aggregate test data
    - b. Summary of concrete yield quantities and compressive strength results
    - c. Summary of cement and pozzolan quantities

### **3. *Independent Quality Assurance Testing Laboratory Requirements***

1. Certification (prior to construction) – ASTM C 1077<sup>31</sup>
  - a. Certifying Authority (AASHTO<sup>32</sup>, CCRL<sup>33</sup>, etc.)
  - b. Tests certified to perform
  - c. QA plan for laboratory
  - d. Documentation of calibration of equipment for tests to be run (weights and measures, screen calibrations, testing machine calibration, nuclear moisture-density gauges including license and operator training records, other test equipment)
  - e. Certification records of testing technicians
2. Daily Reports – Checked data – Same as 3 above, in 2 – Quality Assurance Testing – Typical Requirements and Reporting

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<sup>31</sup> ASTM C 1077 “Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation,” ASTM International.

<sup>32</sup> American Association of State Highway and Transportation Officials.

<sup>33</sup> Cement and Concrete Reference Laboratory.

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3. Monthly Reports – Same as 4 above, in 2 – Quality Assurance Testing – Typical Requirements and Reporting.

### **B. Quality Assurance Testing Requirements – Mass and Roller Compacted Concrete**

Mass concrete is any volume of concrete with dimensions large enough to require that measures be taken to cope with the generation of heat from hydration of the cement and attendant volume change of the concrete to minimize cracking. This may include reinforced structural concrete or un-reinforced concrete where the mass of the structure is sufficient to resist the forces acting against it. Roller-compacted mass concrete is concrete of no-slump consistency compacted by a roller, often a vibrating roller. The requirements for QA testing for mass concrete and roller compacted concrete are similar in nature to that of structural concrete. It is the responsibility of the design engineer and COR to independently verify concrete quality through a specialized QA testing program. Additional measures may be required to minimize the heat generated by cement hydration with resulting potential for thermal cracking. It has been Reclamation's policy to have QA testing performed by in-house construction field laboratories for mass concrete structures, particularly for dams. Due to staffing constraints, experienced field inspection and quality assurance testing personnel may be detailed from other area or construction offices or the Technical Service Center. Typical quality assurance requirements are outlined as follows:

1. **Quality Assurance Strength Testing – Minimum Requirements for Strength Testing (one set – consists of 2 cylinders tested at indicated test age)**
  1. Not less than one set of strength tests *per class* of concrete *per shift*
    - a. Normal testing: tests at 7 and 28 days and at the design test age (90, 180, 365 days, etc.)
    - b. Additional cylinders for testing at 7, 28, 90, 180, and 365 days *each week*
    - c. Additional cylinders for long-term testing (2, 5, 10, and 20 years) cast each month.
2. **Quality Assurance Testing – Typical Requirements and Reporting**
  1. Concrete Batch Plant
    - a. Pre-construction and periodic check requirements

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- i. Aggregate gradation – one per shift during production and during mass concrete placements
    - ii. Cement and pozzolan – manufacturers certification
    - iii. Documentation on admixtures
    - iv. Documentation on scale calibration
  - b. Daily checks
    - i. Moisture content (sand and each size of coarse aggregate)
    - ii. Grading (sand and each size of coarse aggregate)
    - iii. Batch tickets for each load of concrete (including time batched and adjusted scale weights of ingredients)
2. Fresh and Hardened Concrete Tests
  - a. Routine tests (performed on first concrete batched and periodically during placement)
    - i. Slump (or Vebe consistency for RCC)
    - ii. Temperature
    - iii. Density
    - iv. Percent air
  - b. Daily concrete test batch (typically one per class of concrete per day):
    - i. Slump (or Vebe consistency for RCC)
    - ii. Temperature
    - iii. Density
    - iv. Percent air
    - v. Yield summary of ingredients per cubic yard adjusted for grading and moisture
    - vi. W/(C+P) ratio based on yield summary
    - vii. Casting test cylinders (typically two at 7 days, two at 28 days, and two each for other strength-age requirements (90 or 180 days or 1 year)
3. Daily Report (typically reported for each class of concrete)
  - a. Structure identification and location
  - b. Source of concrete (contractor's plant, ready-mix supplier, etc.)
  - c. Placement location (block no., lift no., elevation)
  - d. Yield quantities and total cubic yards of concrete
  - e. Cement and pozzolan content
  - f. Test cylinders cast and test dates
4. Monthly Report (typically for each class of concrete or each aggregate source)
  - a. Summary of aggregate test data
  - b. Summary of concrete yield quantities and compressive strength results
  - c. Summary of cement and pozzolan quantities

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### **C. Reporting Format and Routing**

Materials testing and inspection reports for quality assurance should be stored in a central location, preferably electronically with routine backup. Project Concrete Quality Assurance System (PCQAS) is QA software being designed by Reclamation to work via the internet for collecting QA test data for concrete. The COR should maintain copies of all Government tests and keep these on-site for the duration of the project. The contractor will provide Reclamation copies of their tests if requested. The QA inspection staff is responsible for ensuring the contractor provides documentation in a timely manner.

Daily inspection reports should be prepared by concrete construction representatives and construction inspectors to document contractor activities for compliance with contract requirements. Daily inspection reports will include contractor's QC activities and Reclamation field testing activities performed for a given day, including test results if available.

Monthly construction reports (L-29) with photos and discussions of the month's activities, unusual conditions, quantity of testing, and tabulations of testing results performed by Reclamation should be prepared for distribution to the design team and other entities as required. Reporting should follow standard practices, which are usually set forth in regional or area offices guidelines. These guidelines usually contain example forms for field and laboratory forms. Examples of the L-29 Monthly Construction Report can be obtained by various regional engineering offices, as needed. Reporting formats and content may need to be adjusted to meet the specific needs of the project.

## **VII. Major Quality Assurance Activities**

The QMP should have a list of the major quality assurance items presented under each definable feature of work. The information should be organized using the Construction Specification Institute division. The major activities and associated scope of field inspection activities anticipated for this work should be further defined in this section. A summary of Government QA and Contractor Quality Testing activities is provided in section VIII – Summary Table of Testing Activities.

This section of the QMP provides general direction and an outline of the major QA/QC components of the specification. The specification contains the specific requirements for limits and acceptable values, and controls of materials and workmanship for the completed work. QA/QC activities also apply to any and all

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other work activities not listed in the summary activities. Items not discussed are not to be considered less important.

Information needed for inspection and QA/QC functions may be contained within requests-for-information's, submittals, and/or updates and amendments to the specification not listed in the QMP.

Below is an example summary showing the type of items that should be shown in the QMP. The list can be much longer or shorter depending on the job. A QMP should list specific items for that job. Each definable QA/AC work item below is outlined to address QA/QC requirements, quality related Required Submittal Numbers (RSN), Reclamation QA actions, contractor QC testing actions, and where applicable, necessary corrective action.

### **A. Division 1.0**

#### **1. Quality Procedures**

1. Quality Assurance (QA)
2. Quality Control (QC)
3. Contractor Quality Testing
4. Quality Related RSN's
  - a. RSN 1 – Quality Control Plan

#### **2. Testing Agency Services**

1. RSN 1 – Testing Agency Services Plan
  - a. Names of agencies to perform sampling and testing.
  - b. Agency accreditation to perform specified testing or agency qualifications to perform specified testing.
  - c. Resumes of personnel performing tests.
  - d. Samples of report forms.
  - e. Contractor Quality Testing plan for approval
2. Qualifications
  - a. Testing agency organization
    - i. Agencies testing construction materials: Meet requirements of ASTM E32934.

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<sup>34</sup> ASTM E 329 “Standard Specification for Agencies Engaged in Construction Inspection and/or Testing, ASTM International.

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- ii. Agencies testing concrete and concrete aggregates: Meet requirements of ASTM C107731.
- b. Equipment
  - i. Calibrate measuring devices, laboratory equipment, and instruments at established intervals.

### **B. Division 3.0**

#### **1. Epoxy Grouted Anchor Bars**

- 1. QA/QC Requirements
  - a. Contractor responsible for quality testing
  - b. Required certifications (ACI 355.4<sup>35</sup>)
- 2. Quality Related RSN
  - a. RSN 1 – Product data
  - b. RSN 2 – Instructions
  - c. RSN 3 – Qualifications
  - d. RSN 4 – Pull out test procedure
  - e. RSN 5 – Test results
- 3. Qualifications
  - a. Installed on three similar projects in the past 5 years
- 4. Contractor Quality Testing
  - a. Pull out tests
  - b. Acceptance criteria

#### **2. Concrete**

- 2. QA/QC Requirements
  - a. The contractor responsible for QC
    - i. Contractor Field Quality Testing as specified
  - b. The Government responsible for QA
  - c. Perform tests according to Field Testing, minimum as specified
- 3. Quality Related RSN's
  - a. RSN 1 – Materials/mix design approval data
  - b. RSN 2 – Concrete placement drawings

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<sup>35</sup> ACI 355.4-11 “Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary,” American Concrete Institute.

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- c. RSN 3 – Concrete placement schedule
  - d. RSN 4 – Cement certification and test reports
  - e. RSN 5 – Test reports
4. Reclamation QA Actions – For Example and Not Limited To:
- a. Ensure submittals are approved and work is in compliance with submittals
  - b. Formwork; verify size, shape, location
  - c. Reinforcing steel; verify size, shape, lengths, quantity, and proper placement to approved submittals
  - d. Other embedded items, metal or waterstop
  - e. Verify proper materials proportioning
  - f. Verify hauling and placement requirements are met
  - g. Sample and Test Fresh Concrete Prior to Placement, Cast 6"x12" Strength Specimens
    - i. Test – Slump (ASTM C 143<sup>13</sup>), air content (ASTM C 231<sup>14</sup>), unit weight (ASTM C 138<sup>16</sup>), concrete temperature (ASTM C 1064<sup>15</sup>), and calculate yield
    - ii. Frequency – For each mix placed: test concrete and cast one set of five cylinders for the first 50 cubic yards per day of concrete placement, plus test and cast one set of five cylinders for every 100 yard of concrete placement. At least one test and set of five cylinders per day of placement.
    - iii. If mix consistency is questionable, test slump every load of concrete
    - iv. Tests should be taken at the point of placement
    - v. Requirements – Test two cylinders at seven days, two cylinders at 28 days, and hold one cylinder in the event that the 28 day strength is low.
      - 90 percent of cylinders tested strength to exceed 28 day design strength
      - Average of six consecutive cylinders to exceed 28 day design strength.
      - No individual test to be more than 500 psi below 28 day design strength
  - b. Sample and perform Aggregate Tests (ASTM C 117<sup>11</sup> and ASTM C 136<sup>9</sup>)
  - c. Test Strength Specimens at various ages
5. Contractor Quality Testing Actions – For Example and Not Limited To:
- a. Perform proportioning checks at batch plant and monitor slump (ASTM C 143<sup>13</sup>), air content (ASTM C 231<sup>14</sup>), unit weight (ASTM

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- C 138<sup>16</sup>), and concrete temperature (ASTM C 1064<sup>15</sup>) at least once per shift per mix or when consistency of the mix changes.
- b. Tests for gradations (ASTM C 117<sup>11</sup> and ASTM C 136<sup>9</sup>) and moisture contents (ASTM C 566<sup>12</sup>) of concrete aggregates to maintain concrete consistency and workability.
- c. Make testing reports available to the COR.

### **VIII. Summary Table of Testing Activities**

Providing a table of quality related testing activities in the QMP is an effective way to summarize testing requirements listed in the specification. Below is an example of a table that can be edited for a specific project.

Table 5.—Summary Table of Testing Activities

Material	Type	Property	Reference(s)	Target and Tolerance	Frequency (COR may vary frequencies)	Government Quality Assurance	Contractor Quality Testing
Concrete	Feature – For example, structural concrete	Gradation and fresh properties at batch plant	ASTM C 117 <sup>11</sup> ASTM C 136 <sup>9</sup>	Meets ASTM C 3310 for sand, No. 57 for coarse			X
Concrete		Compressive strength	ASTM C 31 <sup>17</sup> ASTM C39 <sup>18</sup>	Compressive strength tests at 7 and 28-days. Minimum 90% of cylinders > f <sub>c</sub> at 28 days; Minimum average of 6 consecutive cylinder > f <sub>c</sub> at 28 days	Per mix: One test for the first 50 cy, plus one test every 100 cy after that; at least one per days placement	X	
Concrete		Temperature	ASTM C 1064 <sup>15</sup>	50° to 90° F	With cylinder and/or every truck as necessary	X	
Concrete		Slump	ASTM C 143 <sup>13</sup>	Slabs: 1-3 inches Canal lining 1-3 inches Other: 2-4 inches	With cylinder and/or every truck as necessary	X	
Concrete		Air content	ASTM C 231 <sup>14</sup>	Structural: 4-6 % Canal: 5-7%	With cylinder and/or every truck as necessary	X	
Concrete		Water/ cement ratio	Calculated from Batch Tickets	0.45 maximum	Per COR	X	
Concrete		Cementitious content	Verified on Batch Tickets	564 lb/cy minimum	Per COR	X	
Concrete	Feature – For example, canal lining	Thickness	ASTM C 42 <sup>19</sup>	3.5 inches minimum	75 cores	Observation of contractor testing	X