

QC
MANUAL
SECTION

1

QUALITY
CONTROL
GUIDE

QUALITY CONTROL MANUAL SECTION 1

Ready Mixed Concrete

Quality Control Guide



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FOREWORD

The National Ready Mixed Concrete Association's Quality Control Manual is comprised of three separate publications, Section 1, the *Ready Mixed Concrete Quality Control Guide*, Section 2, the *Ready Mixed Concrete Quality Control Checklist* and Section 3, the *Plant Certification Check List*.

This is Section 1 of the quality control (QC) manual. This Guide provides an overall discussion of quality control policy and requirements which will help Management clarify objectives and make decisions concerning the organization and scope best suited to the organization. Selection of quality level will have an important impact on the degree of risk associated with the business and the type of work which can be accepted. This part of the Manual also provides detailed information on what type of equipment will be required for various levels of in-house laboratory testing capability. The manual addresses the basic quality control tests and also lists other advanced test methods.

Section 2 of the quality control manual is designed for use in assigning various activities in the quality control program to specific individuals, departments, or other organizations. If desired, individual pages or sections can be distributed for use in documenting quality control assignments.

Section 3 of the quality control manual has been in use since 1965. It is also published separately. It provides the detailed check list for certification of ready mixed concrete production facilities, including plant equipment and delivery vehicles. Formal plant certification requires inspection by a registered professional engineer and submission of the completed form to the NRMCA. The Check list can also be used for internal inspection of plant facilities and truck mixers for compliance with company quality control plans.

NRMCA QUALITY CONTROL MANUAL

Developed by the
NRMCA RESEARCH, ENGINEERING AND STANDARDS COMMITTEE



QUALITY CONTROL GUIDE

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1. INTRODUCTION

In this age of high demands on quality and dependability of engineering materials and systems on the one hand, and the manufacturer's potential involvement in product liability on the other, well-developed quality control systems have become an indispensable part of doing business in many industries. In addition, ready mixed concrete involves a number of unique factors which require attention.

- (1) Ready mixed concrete is a processed but unfinished material at the time of delivery.
- (2) Quality and uniformity of concrete vary because of a large number of factors. Some are readily identified and controlled; others can be obscure and not so easily controlled.
- (3) The quality of the end product is affected by various factors at different phases of processing:
 - selection and variability of ingredients;
 - their proportions;
 - the thoroughness with which they are combined; and
 - conditions, attendant to transportation, placement and protection of the concrete.
- (4) In its "as sold" condition, the product is perishable and will not remain in the plastic and unhardened condition beyond a limited time, the exact period depending upon circumstances.
- (5) Its ultimate quality, compressive strength, cannot be verified at the time of sale, in contrast to other materials. Steel, lumber, masonry units can all be tested before they are used. Only the ingredients of concrete can be tested in advance.
- (6) The product is subject to frequent testing by others. Negligence or individual interpretation of standard methods of testing occasionally result in a misrepresentation of the true quality of the product.
- (7) Whereas most manufacturing industries enjoy a high degree of standardization of their products, the ready mixed concrete industry is compelled to modify and adjust its product to a host of variables in response to real or perceived needs for the various uses of concrete in a project and to make efficient use of locally available raw materials.

In summary, the complexity of providing a quality product, and having it recognized and certified as such, presents the concrete producer with a fairly clear-cut decision. Use a comfortable safety factor regarding the strength of concrete, its major quality feature, and trust in good luck; or become committed to a well-organized quality control effort. This Guide and the other publications in the NRMCA Quality Control Manual Series will be of help if the latter option is elected.

2. BASIC COMPANY POLICIES

Setting up a quality control organization is merely a part of company-wide quality decision. Obviously, hiring quality control personnel, purchasing the necessary equipment, and implementation of a sampling and testing program do not necessarily assure production of quality concrete. These efforts might only serve to enlighten management on the current shortcomings of company operations and concrete production. Other decisions need to be made to make the quality control organization a worthwhile investment.

2.1 Target Quality

This involves a management commitment to the desired level of product quality. Apart from selection of cement content for the various strength classes of concrete, the decision-making process covers other important matters such as willingness to maintain product quality regardless of competitive pressures. Less important considerations include, for example, setting appropriate limits on the re-use of returned concrete.

2.2 Personnel Policies

Selection of qualified personnel for the operation of plants and truck mixers has a considerable bearing on production of concrete of dependable quality. Plant operators should be capable of operating with a minimum number of errors regardless of outside pressures. They should have the ability to comprehend the effects of various factors on concrete quality and be able to make the right decisions in problem situations. A higher than average degree of alertness, and concern for product quality, is required of truck mixer operators, particularly when working in dry-batch operations. It is their job to take the materials weighed into their units and produce well-mixed concrete. They should be able to use judgment in adjusting its consistency to fit the job specifications. On the job site they protect the company's interests by carefully recording additions of water and other materials to the concrete, and noting any observed malpractice in sampling, placing, handling, and testing. Good people must be attracted and trained to control concrete quality within their various job assignments. Training sessions and seminars are necessary to ensure that each person gets the information needed to perform his or her job effectively.

2.3 Selection and Maintenance of Plant Equipment

Investment in dependable plant equipment, including truck mixers, and appropriate replacement schedules, will govern the capability of an operation to consistently put out a quality product. Higher initial investment may pay off in the long run if it helps reduce or eliminate costly product failures. For example, automated batching controls will reduce the risk of misbatched loads. Complete physical separation and proper identification of cement and fly ash and other supplementary cementitious materials storage will prevent accidental leakage of fly ash into cement bins or errors when batching, and prevent the potentially disastrous effect on concrete performance.

2.4 Materials Selection

Selection of concrete materials strictly on the basis of economy and with disregard to evidence of variable or inferior quality may be counterproductive by tying up quality control personnel in time-consuming efforts to analyze the causes of resulting substandard or variable concrete performance. A poor quality cement may eventually turn out to produce

highly variable concrete strengths; a fine aggregate subject to erratic changes in grading can cause unexplained water demand and result in strength fluctuations. While troubleshooting these problems, the unavailability of quality control personnel for other critical assignments is then liable to magnify the company's quality problems.

2.5 Within-Company Status of the Quality Control Organization

The person in charge of the quality control organization should be directly responsible to the general manager of the company or division of which it is a part. He or she implements management's decision on the quality level of the product; and reports, usually on a weekly basis, on product and production performance. He or she works with the production department to develop means of maintaining and improving the quality level and cost efficiency of production, and monitors their successful implementation. Quality control activities are coordinated with the production and sales departments. In turn, the quality control personnel depend on these departments for information that will result in an optimum contribution by the quality control organization to the company's business objectives. This communication becomes especially important when considering jobs with specifications using statistically-based acceptance criteria with penalty clauses since a knowledge of the level of production variability is critical to the decision to bid.

3. THE SCOPE OF QUALITY CONTROL ACTIVITIES

"Quality Control" has become a convenient label for a number of functions which not only include the design and control of the company's product, but a number of activities only indirectly related to control of quality. Quality control activities usually include:

- sampling and testing of concrete and concrete materials;
- plant and field control of concrete production;
- evaluation and procurement of new equipment and tools to improve quality;
- concrete mixture optimization;
- research and development testing;
- specification review; evaluation of concrete performance; and
- failure analysis and prevention.

Additionally, quality control functions may include personnel training, various promotional activities, and company representation in industry and professional groups.

Refer to Section 2 of the NRMCA Quality Control Manual for a detailed "Quality Control Check list" of potential activities.

4. QUALITY CONTROL ORGANIZATION AND STAFFING

4.1 The Basic Quality Control Service Unit

Staffed by junior quality control technician(s). Control functions of this unit involve primarily the sampling and testing of concrete ingredients and concrete, and control of production at the plant and in the field. It may represent the entire quality control operation of a small company, or may be one of several in a multi-plant company. Some of its functions may be performed by a commercial laboratory, for example, the curing, capping, and testing of strength test specimens.

4.2 The Central Laboratory

Staffed by senior and junior quality control technician(s). The laboratory is usually under the supervision of an assistant quality control manager. It has testing facilities which permit a wide range of in-house testing of concrete and concrete materials. It may be equipped with some or all of the advanced testing capabilities listed in Section 5.2.

4.3 The Quality Control Manager

This person works to implement management's objectives concerning the desirable product quality within the overall quality commitment of the company. He or she establishes quality standards for concrete materials and sets up a quality control plan which specifies scope and frequency of sampling and testing. The QC Manager's assignments usually include

- review of project specifications and selection of job mixtures;
- preparation of concrete mix designs and other product information for approval by the building official or specifying agency;
- evaluation of concrete performance;
- product optimization;
- research and development testing;
- failure analysis and prevention;
- personnel training; and
- advising on technical aspects of promotional activities.

In smaller companies, the functions of this position may be handled by various members of the management team, assisted by outside consultants or laboratories.

5. TESTING EQUIPMENT AND STANDARDS

5.1 Basic Quality Control Functions

The testing priorities of a ready mixed concrete producer's laboratory are primarily directed at those tests which are most important to the acceptance of the product by the customer. Capabilities for testing fresh concrete and the strength (and other properties) of hardened concrete are, therefore, a primary requirement, followed by certain tests for significant properties of aggregates and other concrete materials which have a bearing on concrete performance. Listed below is equipment required for basic quality control tests. Numbers in parentheses refer to applicable ASTM standard test methods. The information is limited to essential pieces of equipment for rough cost estimates.

5.1 .1 Tests on Concrete

- (1) *Accessory equipment*: Wheelbarrow (4 cu. ft.); No. 1 or 2 metallic scoop; tamping rod; mallets with a rubber or rawhide head, for consolidating test samples, wood or magnesium float; steel trowel; 10 quart bucket; short-handled square-end shovel; box of clean rags; work gloves; rubber gloves (neoprene); 6 ft. ruler; 100 ft. tape (for measuring form dimensions); magnifying glass or loupe (10×) to inspect hardened concrete for amount of air or water voids and other characteristics; plywood boards (for providing firm base for molding test cylinders and setting up other equipment on a level base in the field); pocket calculator.
- (2) *Slump test (C 143)*: Cone Mold.
- (3) *Air content - volumetric (C 173)*: Roll-A-Meter, furnished with accessory equipment; isopropyl alcohol, for dispelling surface foam. Can be used for accurate air content determination on all types of concrete, including lightweight concrete and normal weight concrete with porous aggregates. High cement factor concrete may need a longer testing duration before a stable air content reading is obtained.
- (4) *Air content - pressure method (C 231)*: Various types of pressure meters are available. Furnished with calibration and other accessory equipment. Measuring bowls having capacity of 0.2 cu. ft. and more. These containers may be usable for unit weight tests (see C 138). Pressure air meters are not for use with lightweight aggregate concrete, or with high porosity aggregates. Aggregate correction factor should be applied to the measured air content..
- (5) *Unit weight and yield (C 138 and C 29)*: Unit weight bucket (½ cu.ft.); strike-off plate – ¼ in. thick metal plate, ½ in. thick glass or acrylic plate; ¼ in. thick glass plate, water pump, and chassis grease for calibration procedure. Platform scale, capacity depending on size of unit weight measure and expected weight range of concrete.
- (6) *Concrete temperature (C 1064)*: A good quality bi-metal thermometer with large dial face readable and accurate to within ±1°F. Liquid-in-glass thermometer accurate to within ±0.5°F for calibration of bi-metallic field thermometers.
- (7) *Cylinder molds (C 470)* various types as follows (in order of frequency of use):
 - Plastic, single use* - permit easy stripping; attention required to possible deformation from squeezing if cylinders are moved while concrete is plastic; must be set on firm base to prevent downward bulging of bottoms and resultant convexity of cylinder ends, which causes lower measured strength.
 - Heavy Plastic, multiple use* - removed by controlled air pressure through hole in the base. Caution should be used when removing concrete test specimens from these molds. Repeated use results in outward bulge of cylinder bottoms and convexity of cylinder ends leading to lower measured strengths.
 - Waxed cardboard, with metal base* - provide better rigidity and resistance to deformation than plastic molds. Wax coating may melt under exposure to heat or sun, with wax penetrating concrete, thereby causing difficulty in stripping molds. Erratic strengths were recorded when cylinders using these molds were placed in steam curing environment. Outside surfaces of molds should not be allowed to become wet as the expansion of cardboard fibers may damage the concrete cylinder. Some types of

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molds have plastic inside coating. Scuffing the lining during rodding operation allows water to penetrate paper fibers causing swelling and deformation of plastic concrete in the mold. Accidental striking of metal base with the tamping rod causes protrusions in cylinder bottoms which necessitate thick caps for strength testing. These result in lower measured strengths.

Tin molds, single use - of the various mold types, these are reported to produce cylinder strengths nearest to those obtained from cylinders molded in reusable steel molds (see below). However, they are easily deformed out of roundness from careless handling. Bottoms are easily damaged by accidental striking with tamping rod. Tin molds may also leak water from crimps in joints.

Steel molds, reusable - provide highest cylinder strengths of various types of molds. Involve extra labor cost from time-consuming cleaning and re-assembly to ensure water tightness. No capping is required if machined end plates are used and cylinders are stored horizontally. However, horizontally-stored cylinders produce 5 to 10 percent lower strengths.

- (8) *Flexural strength test (C 31, C 192, C 78)*: Beam molds are usually of 6 × 6 × 21 in. dimensions. Consideration should be given to ease of handling (low weight), cleaning and assembly when selecting type of mold. If large number of tests are involved, use a vibrator, 1 in. maximum diameter; minimum 7000 vibrations per minute, for consolidation of low slump concrete. The vibrator may have to be powered by portable generator if operated away from regular power source. Wood or magnesium float for finishing beam surface. Use a trowel to space the sides. Load application apparatus (single-point or third-point).

- (9) *Curing facilities (C 511)*:

Low volume operation for strength testing - Use a curing tank filled with saturated lime water (calcium hydroxide). Galvanized steel cattle trough, or equal, with temperature recording device inserted in water for control of 73.4±3°F temperature requirement. Unless located in temperature-controlled environment, provide for automatic temperature adjustment by means of heating/cooling elements.

High volume operation for strength testing - Moist room capable of maintaining free moisture on specimen surface at controlled temperature of 73.4±3°F. This condition can be obtained by various methods, including combination of heating/cooling air conditioner and humidifier; or A/C unit with a water atomizer using compressed air from plant air compressor and water from available source.

Flexural strength tests - Curing tank filled with saturated lime water (calcium hydroxide) for curing a minimum of 20 hours before the flexure test. Note that without this final curing phase and immediate testing after removal from water, the measured flexural strength of test beams may be reduced by as much as 10 percent and more.

- (10) *Cylinder capping (C 617 and C 1231)*: Most practical and economic method is that using sulfur capping compound. The method involves use of the following items:

Capping fixture or jig -- With machined steel base plate, min. 5/8 in. thick. Note that the ASTM Standard permits ½ in. thick plates. However, plates of this thickness with welded-on retaining rings deform from the heat of capping compound and cause

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convexity of cap surfaces and lower measured strength. Use of a two-piece metal plate permits re-machining of the base plate to eliminate gouges or dents from continued use.

Compound melting pot - Size depends on testing volume. For high volume, use automatic roaster ovens available at kitchen supply houses and discount stores.

Capping compound - For optimum strength use commercial high-strength compound and limit re-use of reclaimed material. For additional precautions see Manual of Aggregate and Concrete Testing, Appendix to Part 04.02, Annual ASTM Book of Standards. Strength of the compound should be periodically verified by means of 2 in. cubes prepared in accordance with C 617.

Neoprene pad capping (Unbonded) -- Retaining ring system to hold neoprene rubber pad; durometer hardness of pads varies from 50 to 70, depending on strength of concrete tested. Pad caps may not be appropriate for concrete strengths below 2000 psi or higher than 7000 psi. Maximum number of reuses may be limited to about 100. The pad cap system should be qualified by correlating with sulfur-capped cylinders. Number of reuses needs to be verified with companion sulfur capped cylinders.

- (11) *Testing machine (C 39)*: Must be power-operated and have controlled rate of loading to conform with C 39. Therefore, small manually-operated machines may not be a sound investment for a producer laboratory if the strength test data should carry any weight in disputes over strength test results obtained by an outside agency. For greater accuracy in higher load range, allow for capacity well in excess of the highest anticipated loads. Select machine with more than one load range if testing of other than structural concrete cylinders is expected (flexural or tensile splitting strength; 2 in. mortar cube tests). Special accessory tools may be required for testing of specimens other than 6 × 12 in. cylinders.
- (12) *Rebound hammer test (C 805)*: Several sizes and types of rebound hammers are available. Useful for determination of approximate in-place strengths of concrete.

5.1 .2 Tests on Aggregates

- (1) *Aggregate moisture*:

Aggregate drying method (C 566) -- Usable for fine and coarse aggregate; hot plate or drying oven (230°F); drying pans (size depending on sample size required by C 566); scales accurate to at least 1 gram, capacity according to required sample size. Aggregate absorption required for determination of aggregate surface moisture.

Chapman Flask or Pycnometer (C 70) -- Chapman Flask or other graduated flask; or pycnometer; scale. Primarily for determination of fine aggregate surface moisture. Aggregate specific gravity required for result determination.

Speedy Moisture test: Self-contained unit; moisture readout on pressure gauge actuated by gas pressure developed from aggregate surface moisture which reacts with calcium carbide powder which is also placed in the pressure vessel.

- (2) *Fine aggregate gradation (C 136)*: Sample splitter of appropriate size; hot plate or drying oven (230°F); scale; mechanical sieve shaker with horizontal and vertical movement and tapping action ("Ro-Tap" or equal); nest of sieves, 8 in. diameter, having screen sizes of 3/8 in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No.

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200, cover and pan.

- (3) *Coarse aggregate gradation (C 136)*: Sample splitter of appropriate size or means for hand-quartering down to sample size; drying at 230°F (not mandatory for rapid control tests); mechanical screen shaker; set of screens for most frequently used coarse aggregate sizes, usually 1½ in., 1 in., ¾ in., ½ in., 3/8 in., No. 4 and No. 8.

- (4) *Other basic aggregate tests*:

Materials finer than No. 200 sieve (C 117) -- Fine aggregate sieves No. 16 and No. 200; drying oven (230°F); container or vessel for aggregate washing; scale.

Specific gravity and absorption of coarse aggregate (C 127) -- Wire basket; scale; hot plate or drying oven (230°F); apparatus for suspending sample container (wire basket) in water under scale; box of clean rags or towels (terry cloth or equal).

Unit weight and voids content in aggregate (C 29) -- Unit weight container (½ cu. ft.); platform scale, min. 100 lb. capacity; drying oven (230°F); thermometer; glass plate (the last two items required for calibration of unit weight measure).

NOTE: Test for specific gravity of fine aggregate (C 128) requires operator dexterity and is not very frequently done because fine aggregate deposits show fairly uniform specific gravity. It is therefore omitted from this list. Consider using an experienced commercial laboratory if this test is required.

5.2 Advanced Testing Capabilities

Equipment includes that for basic QC functions and equipment listed below.

5.2 .1 Tests on Concrete

- (1) *Trial batches (C 192)*: Laboratory mixer (revolving drum type) with capacity for making a minimum of six 6×12 in. cylinders per batch and sufficient concrete for slump, air, unit weight tests, typically about 2 cu.ft.. Bunkers for holding different aggregate types and sizes. Facilities for pre-soaking of coarse aggregate. Large size aggregate shaker for separating and accurate recombining of aggregate size groups for controlled comparison testing for effects of various mix variables on strength and other concrete properties. Batch scale, preferably dial type, 100 lb capacity. Pipettes and graduates for accurate measuring of admixture quantities. Special laboratory operating practices for uniformity and consistency in trial batch preparation.
- (2) *Setting time of concrete (C 403)*: Proctor penetration resistance apparatus; rigid, nonabsorbent containers of 6×6×6 in. minimum size; pipette. Effect of hardening rate of concrete of variables such as different cements, admixtures, mix proportions, and concrete temperatures are determined with this method.
- (3) *Splitting tensile strength (C 496)*: Supplementary bearing plate or bar for the testing machine; special jig for aligning concrete cylinders and bearing strips. Test used for determination of design coefficients applicable to various lightweight aggregates and lightweight concrete mix compositions. Also used in place of flexural strength tests after strength correlation have been established, although not qualified as acceptance test.
- (4) *Core testing (C 42)*: Core drill. Drill bits for various core diameters, typically 3 to 4 inch. Portable generator, if electric power is unavailable. Concrete saw for

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preparation of core ends. Capping rig for core diameter less than 6 in.

- (5) *Penetration resistance test (C 803)*: Windsor probe unit. Measures resistance of concrete to penetration by a steel projectile propelled by a measured powder charge. Usually considered a more reliable indicator of in-place concrete strength than the rebound hammer.
- (6) *Petrographic examination (C 856)*: Loupe for 10x magnification. Stereomicroscope to 70x magnification. Diamond saw; polisher; abrasives of various fineness; resin or wax for impregnating surface to be polished; hot plate or oven for impregnating and drying of specimens. Basic defects in hardened concrete (high air content; excessive water voids) can be rapidly identified with this equipment. More detailed examination requires services of skilled petrographer and specialized equipment. See C 856 for additional information.

5.2 .2 Tests on Aggregates

- (1) *Specific gravity and absorption of fine aggregate (C 128)*: Balance of 1 kg min. capacity; pycnometer; metal cone mold; tamper.
- (2) *Sand equivalent test (D 2419)*: Check the ASTM Method for equipment requirements. Method measures quantity of detrimental fine dust and clay in fine aggregate.
- (3) *Organic impurities (C 40)*: Graduated glass bottles; reagent sodium hydroxide solution; reference color standard solution (potassium dichromate dissolved in sulfuric acid), or color reference plates.
- (4) *Resistance to Degradation by Abrasion and Impact in Los Angeles machine (C 131 and C 535)*: Los Angeles abrasion machine; abrasive charge. Measures the degradation of coarse aggregate from impact and abrasive wear.

5.2 .3 Tests on Cement

Testing of cement is advisable if strength fluctuations are experienced for which no assignable causes in properties of concrete or concrete materials can be determined. With a moderate expense in labor and equipment, basic information on cement performance can be obtained including compressive strength of cement mortar cubes, time of set, early stiffening (false set; flash set), and water demand. Note that equipment for strength tests of cement mortar cubes is usable for determining uniformity and strength contribution of fly ash, blast-furnace slag and other pozzolans; for strength tests of capping compound; and effects on mortar strength of non-potable mix water, recycled wash water, and of organic matter in fine aggregate. The reliability of test results is gauged by running replicate tests and between-laboratory tests for degree of compliance with the precision statement applicable to the specific method of test. The success of a cement testing program requires that sampling is done in strict compliance with applicable standards (C 183; C 917) and is handled by responsible personnel.

Listed below are basic equipment requirements for various tests on cement.

- (1) *Compressive strength of cement mortars C 109*: 2 in cube molds; graded Ottawa sand (C 778); 4 quart mixer (C 305); glass graduates; scale; tamper; trowel; flow table, flow mold and caliper (C 230); moist cabinet or curing room; testing machine with 0 to 60,000 lbs. load range; testing machine with attachments for testing 2 in. cubes. Note that flow test is required in testing blended cements (C 595). Flow of portland

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cement mortars is a useful indicator of the mix water demand of a cement.

- (2) *Time of setting by Vicat Needle (C 191)*: Vicat apparatus with 300 g plunger with steel needle, 1 mm dia.; glass graduates; scale; conical ring mold; glass plate; mixer (C 305). Initial set is attained when needle penetrates 25 mm into cement paste sample (at normal consistency) having a depth of 40 mm; final set when no visible sinking of needle into sample is observed.
- (3) *Time of setting by Gillmore Needles (C 266)*: Gillmore Needles, consisting of one "initial set" needle, 1/12 in. dia., 1/4 lb. weight, and one "final set" needle, 1/24 in. dia., 1 lb. weight; glass graduates; scales; mixer (C 305); glass plate. Initial set is attained when a cement paste pat will bear initial set needle without appreciable indentation by the final set needle.
- (4) *Normal consistency C 187*: Vicat apparatus with 300 g plunger, and plunger end having 10 mm dia., conical ring mold; glass graduates; scales; mixer (C 305); non-absorptive plate. The determination of normal consistency provides information on quantity of mixing water to be used in time of setting tests by Vicat and Gillmore Needles. Normal consistency of a cement paste is attained with that amount of mix water which will cause the plunger to settle at a point 10 ± 1 mm below the surface 30 seconds after release of the plunger. The test provides supplementary information on the mix water demand of cement in concrete.
- (5) *Early stiffening of portland cement (mortar method) (C 359)*: Modified Vicat apparatus with 400 g plunger with plunger end of 10 mm. dia.; containers, 50×50×150 mm, for holding mortar samples; graded Ottawa sand and 20/30 standard Ottawa sand (C 778); graduates; scale; mixer (C 305); interval timer. Rate of plunger penetration is measured for initial, 5 min., 8 min., 11 min., and remix penetration. If remix penetration is appreciably greater than earlier penetration rates, the cement may have false set tendencies.
- (6) *Early stiffening of portland cement (paste method) (C 451)*: Vicat apparatus as used in the normal consistency test (C 187); graduates; scale; mixer (C 305); conical ring mold; glass plate; interval timer. Initial, final (5 minute), and remix penetration are measured. If remix penetration is appreciably greater than the final penetration, the cement may have false set tendencies.

NOTE: A cement with severe false set characteristics may adversely affect the performance of concrete to a greater extent than is normally assumed. Even after mixing through the early stiffening phase and restoring the plasticity of the concrete, it may exhibit abnormal bleeding, poor workability, erratic strengths, and variable air content, if the concrete is air-entrained. A high degree of batch-to-batch variability has also been observed when a false setting cement is used in laboratory trial batches of concrete.

Additional physical tests on cement may be found to be useful, including tests for fineness, or loss on ignition. These require more sophisticated equipment and additional operator training in following prescribed testing procedures. See methods of test as described in Part 04.01 of the Annual Book of ASTM Standards.

5.2 .4 Tests on Admixtures

Performance of admixtures in concrete, including air-entraining, chemical and mineral (pozzolanic) admixtures, is usually evaluated by means of trial batches in which characteristics of concrete containing admixtures are compared to those of a plain reference concrete. Equipment for these is as listed in Paragraph 5.2.1, Tests on Concrete.

The procedure applies to new materials, to new cement-admixture combinations, and to admixture stock with suspected abnormal performance in the field.

- (1) *Liquid admixtures*: Due to highly controlled manufacturing processes, they show good lot-to-lot uniformity. Freezing may cause a settling out of solids. Homogeneity can usually be restored by mechanical agitation and can be determined by density measurements with a hydrometer. (NOTE: Remixing should never be done by sparging with compressed air. Carbon dioxide in the air may change the admixture pH and destabilize the admixture chemistry.)
- (2) *Mineral admixtures -- fly ash*: Being a by-product of power plant operation, its properties may change depending on type and origin of coal used, varying levels of power generation, and other factors. Uniformity of a fly ash can be monitored by various tests, including: color comparison, the simple foam index test for effect on air entrainment (see Section 2.2.3 of the NRMCA Quality Control Check list); material retained on the No. 325 sieve for amount of large particles (C 430); loss on ignition for carbon content and moisture (C 311); and for pozzolanic activity index (C 311). See the individual methods for equipment required in these tests.
- (3) *Mineral admixtures -- slag*: When used in combination with portland cement in suitable amounts, ground granulated blast-furnace slag (GGBFS) is capable of substantial strength contributions to concrete. Slag is rated by different grades as defined in the Specification C 989. Generally, the strength contribution of a slag increases with its fineness of grind and the content of non crystalline or amorphous minerals (glass). Due to the uniformity of slag from a given source, control testing may not be necessary or only at considerable intervals. The most practical method for testing the quality and uniformity of slag is the strength test of 2 in. mortar cubes in accordance with a modification of the C 109 test for strength of portland cement mortar. The procedure is described in C 989.

5.3 Quality Control of Laboratory Operations

A quality control operation represents a sound investment only if it generates reliable information. Erroneous test data may either produce a false sense of security, or lead to action inappropriate to the occasion, to the detriment of the producer's business. Testing errors are the result of incorrect testing procedures, mistakes in processing of samples and specimens, or equipment out of calibration. The following measures taken at regular intervals will help to control these potential causes of testing errors.

- (1) Quality control staff is examined for proficiency in test procedures. Results are recorded. Technician certification is available from a number of organizations, including ACI, NRMCA, NICET, and state transportation departments.
- (2) Verification that QC staff are knowledgeable on quality limits and, when failure to meet these limits occur, respond with the proper action.
- (3) Audit procedures for identification and processing of specimens, and record-keeping

of results.

- (4) Within-test uniformity and uniformity of replicate tests on same sample are evaluated.
- (5) Reliability of strength test results on concrete is evaluated through comparison testing on same samples jointly with an outside laboratory.
- (6) Ensure that equipment is calibrated. Processing materials (including capping compound; cylinder molds; graded Ottawa sand; etc.) are checked for properties in conformance with applicable methods of test. A laboratory calibration manual is maintained in which calibration schedules are listed and results of calibrations, adjustments, and corrective actions are recorded.

5.4 Laboratory Evaluation and Accreditation

Whenever self-inspection of a producer laboratory indicates a satisfactory status, appropriate credentials should be sought which will document the laboratory's qualifications to the outside world. Documentation of this type is available by way of periodic inspections by the ASTM-sponsored Cement and Concrete Reference Laboratory (CCRL) of the National Institute of Standards and Technology (NIST), and through accreditation by the U.S. Department of Commerce through its National Voluntary Laboratory Accreditation Program (NVLAP), the AASHTO Accreditation Program (AAP), and the American Association for Laboratory Accreditation (A2LA).

- (1) *CCRL Inspection:* The CCRL representatives determine compliance of laboratory staffing, equipment and procedures with applicable standards and document the laboratory's compliance status in a summary report. The report gives no ratings and its contents are not to be used for general promotional purposes. It may, however, be shown to interested parties to substantiate the laboratory's qualifications. The fact that a producer laboratory is CCRL-inspected confers a certain reliability status to its data that may be important to the producer's dealings with customers and building officials. Information regarding this inspection program can be obtained by writing to

Cement and Concrete Reference Laboratory,
National Institute of Standards and Technology
Building 226, Room A 365
Gaithersburg, Maryland 20899.

- (2) *NVLAP Accreditation:* The competency of a laboratory in the most important tests on field concrete can be documented through accreditation by the U.S. Department of Commerce. Accreditation is given following successful completion of a process which involves submission of an application and payment of fees, followed by an on-site visit, proficiency testing, deficiency resolution, technical evaluation and administrative review. While NVLAP uses its own assessors for on-site visits, they accept assessments by the Cement and Concrete Reference Laboratory Program. NVLAP requires laboratories to participate in CCRL's cement and concrete proficiency sample programs. Accreditation confers a more visible degree of recognition of a laboratory's proficiency in the testing of concrete. A laboratory may publicize its accredited status and use NVLAP logos on test reports, stationery and in business and trade publications. Information on the accreditation process is summarized in the NVLAP Concrete LAP Handbook, which can be obtained by writing to:

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National Voluntary Laboratory Accreditation Program
Construction Materials Testing,
National Institute of Standards and Technology
Gaithersburg, Maryland 20899.

- (3) *The AASHTO Accreditation Program (AAP)*: The American Association of State Highway and Transportation Officials (AASHTO) established the AAP in June of 1988. The objective is to provide a mechanism for formally recognizing the competency of testing laboratories to perform specific tests on hydraulic cement and portland cement concrete, besides other construction materials. AASHTO recognizes a laboratory's compliance to the requirements of ASTM Practice C 1077. AASHTO accreditation is available to all laboratories including independent laboratories, manufacturers' in-house laboratories, university laboratories and governmental laboratories. Central laboratories of State Departments of Transportation will typically obtain AASHTO accreditation. The AAP utilizes laboratory inspection and proficiency sample services provided by the AASHTO Materials Reference Laboratory (AMRL) and the Cement and Concrete Reference Laboratory (CCRL). AMRL and CCRL are Research Associate programs located at the Building and Fire Research Laboratory of the National Institute of Standards and Technology (NIST). For more information on AAP write to:

AASHTO Material Reference Laboratory
National Institute of Standards and Technology
Building 226, Room A 365
Gaithersburg, Maryland 20899

- (4) *American Association for Laboratory Accreditation (A2LA)*: is a nonprofit, scientific membership organization dedicated to the formal recognition of testing laboratories and related organizations which have achieved a demonstrated level of competence. Accreditation is available to all laboratories regardless of whether they are owned by private companies or government bodies. On-site assessments of applicant labs are performed for conformity with equipment and procedures. Accreditation will list specific tests and types of tests for which the lab has been found competent. A2LA uses CCRL Proficiency Sample programs. For more information write to:

American Association for Laboratory Accreditation
656 Quince Orchard Road
Gaithersburg, Maryland 20878

6. COMMUNICATIONS

The usefulness of a quality control department depends to a large extent upon its participation in the flow of communications within the organization. In Appendix A, a communications model is presented which illustrates the desirable flow of communications involving the quality control organization at various phases of a project.

7. PERSONNEL TRAINING

The quality control department provides the producer with the technical and teaching resources for advancing the professionalism of other company personnel. A basic understanding of concrete technology and of the company's quality standards fosters personal involvement in product quality and will lead toward making the right decisions in problem situations. The qualification of quality control personnel for their teaching functions is built up through attendance at industry seminars and short courses, through a study of pertinent publications, and correlation of theoretical information with practical experience in the field. Training aids, either prepared in-house or obtained from outside sources, are used to lend substance to the training sessions and make them interesting. See Appendix B1 and B2 for information on the range of instruction subjects and on sources of training programs. The effectiveness of the training sessions is enhanced by scheduling a quiz at the end of each session. The prospect of a quiz will make for a more attentive audience; it will also provide a means for gauging the success of the teaching efforts.

8. PROMOTIONAL ACTIVITIES

The promotional value of a company's quality control operation can be more fully realized through its involvement in various activities such as

- (1) promoting the company's business by demonstrating a sound technical knowledge of the product;
- (2) improving the handling by the customer, and the testing by others, of the company's concrete;
- (3) working toward a wider use of concrete by owners, designers, and builders.

8.1 Promoting the Company Business

- Presentation to customers of performance records on previous major or special projects, including records of dependable early strengths of concrete (as required in high-rise construction).
- Demonstration of the scope and qualifications of the company's quality control organization, including reference to its participation in inspection and accreditation programs of outside agencies.
- Documentation of plant and mixer inspection schedule and plant certification, if applicable.
- Assistance to customers toward cost efficiencies and quality improvements in placing

and finishing concrete.

- Distribution of technical literature including NRMCA Concrete In Practice brochures and other publications with the company imprint, as applicable to various job situations.

8.2 Promoting Good Practices in Handling and Testing of Concrete

- In conjunction with other concrete producers, and with assistance from outside organizations, schedule seminars for local builders, contractors and concrete finishers in which the basics of quality concrete and proper practices for obtaining strong, durable and crack-free concrete are explained. Suitable subjects include: control of mix water content; importance of air-entrainment; cold and hot weather concreting; crack prevention in flatwork through correct joint design; and benefits of proper curing of concrete.
- Finishing demonstrations emphasizing the importance of correct timing of finishing operations.
- Demonstration with local testing agencies on correct testing practices and discussion of adverse effects of various improper testing procedures.

8.3 Promoting Uses of Concrete and Realism in Concrete Specifications

- In presentations directed at owners, designers, and builders, and with engineering support from industry associations, explain the advantages and efficiencies of using concrete in various applications including tilt-up construction; city street and parking lot pavements; thermal insulation value due to concrete mass factor.
- Sponsor manufacturers' presentations on innovations in the use of various chemical and mineral admixture and benefits imparted to handling characteristics; hot weather performance of concrete; and durability of concrete. In general, the versatility of concrete as a construction materials should be demonstrated.
- Schedule panel discussions on realism in concrete specifications, including cost-effective use of local materials; need for appropriate tolerances in strength, slump and air-entrainment; reduction in job mix variables for optimum plant control of concrete; limitations of the water-cement ratio concept in mix design and field control of concrete; and sampling and testing of concrete -- the right way.
- Suggest standard practices for ordering concrete which will help ensure that concrete of the proper quality level will be provided for typical local uses in commercial and residential construction.

9. COMPANY REPRESENTATION IN INDUSTRY AND PROFESSIONAL GROUPS

- Technical Industry Committees: Membership in these provides participation in efforts of improving industry standards and of technical specifications on concrete including those of governmental agencies.
- Specification-Writing Groups: These offer a direct forum for presenting the industry point of view on existing and upcoming standards governing materials specifications and methods of test. Membership on ACI and ASTM Technical Committees and

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regular attendance at these Conventions. Generally these Societies meet twice a year. Participation in local ACI Chapters.

- Professional Associations: Personal involvement in these, and presentation of special programs, serve to advance the reliance by design professionals on concrete as a versatile and dependable building material.
 - Membership on the technical committees of your state ready mixed concrete association.
 - Membership on NRMCA committees. Contact NRMCA for further information.
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APPENDIX A

Job Progress Communications

Job Phase	Information	From	To	Action Required
Planning Stage (Owner or A/E)	Type of project; Job size	Sales	QC	Provide specification input (see 8.3 on Realism in Specifications). Present performance histories of concrete and aggregates to out-of-area A/E offices. Forward to owner information on long-term benefits of concrete pavements and parking lots.
Solicitation of Bids	Availability of specifications	(a) Sales (b) QC (c) QC (d) QC	QC Sales Materials Operations	Specification review; obtain clarification from A/E as needed. Mix recommendations for price quotations. Determine availability and cost of special materials. Input on special delivery requirements and equipment for cost estimate.
Pre-Bid Conference	Where and When	Sales	QC	Resolution of conflicting and overly restrictive specification requirements. Clarification of responsibilities for special items (for example, site addition of admixtures) Provisions for extra testing costs if high strength concrete is specified.
Job Award	Name of Contractor	Sales	QC	Technical information to contractor, including performance history of company's concrete on previous similar jobs. Available performance options for rapid form cycling or reducing labor costs.
Selection of Concrete Supplier	"Job Sold!"	(a) Sales (b) QC (c) QC (d) QC (e) QC	QC Materials Operations Dispatcher Accounting	Mix design submission Order special concrete materials Batching information to batch plants List of job mixes, with "red flagging of special mixes, special concrete properties and delivery requirements Mix identification and material quantities
Pre-Construction Conference	Where and When	Sales	QC	See Quality Control Check list (Section 2 of Quality Control Manual) and Appendix C of that Section.
Job Start	Advance notice of first delivery	Sales	QC	Pre-test special materials for specification compliance. Review plant handling of materials (for example, pre-wetting of lightweight aggregate to be used in pump placements). Correctness of batching information.
Job in progress	Placement schedule	Dispatcher	QC	QC representative reviews next day's orders for correct mix use and to assign QC field personnel on basis of job priorities and the type of concrete ordered.
	Test reports from independent lab Customer comments on product performance	(a) QC Mgr. (b) QC Mgr.	QC Staff Management	Log test data; investigate causes of strength fluctuations and of other job problems. Weekly review of product performance; recommend action as needed to maintain specification compliance, product uniformity, and customer satisfaction.
	Driver Notes on Delivery Ticket	Operations	QC	Notes on slump control, addition of retempering water or admixtures, and testing practices. Customer-related safety issues must receive immediate attention.
Job Completion	Summary of test data; statistical evaluation	QC	Management Operations Sales	Review of performance level of plants. Recommendations for mix optimization in future projects. Suggestions for promotional use of job data.

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APPENDIX B-1

Subjects for Personnel Instruction

Quality Control Staff	
<ul style="list-style-type: none"> • Sampling and testing of concrete and concrete materials • Batch data preparation • Mix design Submission • Batch plant and mixer inspection • Quality limits and action on non-compliance • Investigation of abnormal test results (in-house and other) • Statistical evaluation of strength data • Communications with customers • Job site control functions • Slump control procedures 	<ul style="list-style-type: none"> • Proportioning concrete mixes; trial batches • Laboratory procedures • Laboratory quality control • Trouble shooting and report writing • Schedule of testing and job priorities • Processing and filing of test reports • Specification review • Innovations in concrete technology • Safety procedures
<p style="text-align: center;">Plant Operators</p> <ul style="list-style-type: none"> • Basic concrete technology • Types of concrete and concrete materials • Aggregate moisture tests and adjustments • Effects of changes in materials (gradation; specific gravity) • Slump control procedures • Plant inspection (NRMCA Plant Check list) • Company policy on handling of returned concrete • Disposition of misbatched loads • Inventory taking and potential causes of inventory losses • Mechanics of scale train and other batching equipment • Yield adjustments on lightweight concrete • Quality control procedures by materials handlers • Response to rejection of concrete loads <p style="text-align: center;">SEE NRMCA PLANT OPERATOR MANUAL</p>	<p style="text-align: center;">Truck Mixer Operators</p> <ul style="list-style-type: none"> • Basic concrete technology • Types of concrete and concrete materials • Mixing requirements, initial and after water additions • Slump control procedures • Company policy on job site water additions • Mixer maintenance (NRMCA Plant Check list) • Testing methods and recognizing improper procedures • Company policies on handling of returned concrete of apparently misbatched loads • Correct practices in handling and finishing concrete • Handling of customer complaints about product quality • Response to rejection of concrete at the site <p style="text-align: center;">SEE NRMCA TRUCK MIXER DRIVER'S MANUAL</p>
<p style="text-align: center;">Dispatcher/Office Personnel</p> <ul style="list-style-type: none"> • Basic concrete technology • Types of concrete and concrete materials • Slump control procedures • Mix identification system • Handling of customer complaints and claims regarding product quality • Response to rejection of concrete at the site • Company policy on handling of returned concrete • Within-company communications 	<p style="text-align: center;">Sales Representatives</p> <ul style="list-style-type: none"> • Basic concrete technology • Types of concrete and concrete materials • Mix identification system • Specification review • Handling of customer complaints and claims regarding product quality • Response to rejection of concrete at site • Testing methods and recognizing improper procedures • Within-company communications • Slump control procedures • Strength test reports and promotional use • Innovations in concrete technology - selling added value

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APPENDIX B-2

Information on Training Seminars and Courses

The following organizations offer a variety of publications, training aids, and training courses. Contact them for annual publication catalogs and course offerings:

American Concrete Institute (ACI)
38800 Country Club Drive
Farmington Hills, Michigan 48333
Phone: (810) 848-3700
Fax: (810) 848-3701

American Society for Testing and Materials
(ASTM)
100 Barr Harbor Drive
West Conshohocken, Pennsylvania 19428
Phone: (610) 832-9500
Fax: (610) 832-9555

American Society for Concrete Construction (ASCC)
2025 South Brentwood Blvd, Ste 105
St Louis, MO 63144-1833
Phone: (314) 962-0210
Fax: (314) 968-4367

International Concrete Repair Institute (ICRI)
3166 S. River Road, Suite 132
Des Plaines, IL 60018
Phone: (847) 827-0830
Fax: (847) 827-0832

National Ready Mixed Concrete Association
(NRMCA) 966 Canal Center Plaza, Suite 250,
Alexandria, VA 22314
Phone: 703-706-4800
Fax: 703-706-4809

Portland Cement Association (PCA)
5420 Old Orchard Road
Skokie, Illinois 60077-1083
Phone: (847) 966-6200
Fax: (847) 966-9781