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Guide for the Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment

Reported by ACI Committee 304

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This guide includes a short history of and information on the basic design and operation of equipment used to produce concrete by volumetric measurement and continuous mixing (VMCM), frequently called mobile mixers. Definitions, applications, and quality assurance testing are discussed. The use of this equipment is compared to weigh-batch-mix equipment for some of the limited differences.

Keywords: admixtures; **aggregates**; **batching**; calibrating; cements; cold weather construction; colored concrete; concrete construction; field tests; **fresh concretes**; grout; hot weather construction; material handling; measurement; **mixing**; **mixing plants**; **mixing time**; mix proportioning; polymer concrete; precast concrete; process control; **production methods**; shotcrete; slump; **transit mixers**.

CONTENTS

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CHAPTER 1—INTRODUCTION

1.1—General

The purpose of this document is to offer guidance on volumetric-measurement and continuous-mixing (VMCM) concrete production. It contains background information on this method and items to be considered when using it. A discussion of other types of continuous-measurement equipment (i.e., conveyor belt scales or weigh-in-motion scales) is outside the scope of this report.

1.2—Discussion

The title uses the words "volumetric measuring" and "continuous mixing." The significance of these words in the context of this guide are discussed in the following paragraphs.

Volumetric measurement—When the ingredients of concrete are flowing continuously and measured by volume, by using a calibrated rotary opening, a calibrated fixed-gate opening, or a combination of these, so that a known, predetermined volume of each ingredient is obtained in a designated time interval, the method of measurement is volumetric. Continuous volumetric measurement with multiple ingredients requires that the proper relationship among those ingredients be maintained.

Continuous mixing—When the output of the mixer is equivalent to the input of materials and the mixer can be operated without interruption to charge or discharge material, the mixer can be considered continuous. The mixer may be started and stopped as required to meet production requirements (provided that material input is also started and stopped). Such a mixer is suitable for both continuous or intermittent operation.

1.3—History

Volumetric measurement and continuous mixing have a long history of producing concrete. For many years, the concept of "one shovel of cement, two shovels of sand, and three shovels of stone" was used to produce concrete. Patents on continuous mixers date back at least to 1913. It was not until these two technologies were successfully combined in the early 1960s that general field use of this type of equipment began. The first commercial unit was delivered in 1964. Because of the detail of original patents, there was only one manufacturer of VMCM units until the early 1980s, when other manufacturers began to offer this type of equipment for concrete production.

By the mid-1970s, there were over 4000 VMCM machines in operation in the U.S. Generally, they were used to produce small volumes of concrete. During the late 1970s and early 1980s, specialty concretes needed for bridge-deck renovation and highway repair, which were difficult to produce in conventional transit mixers, were being produced successfully by VMCM equipment. This application gave the equipment credence and showed it could produce close-tolerance, high-quality concrete consistently. VMCM equipment has been considered by some people to be limited to producing special mixtures or small volumes; however, VMCM may be suitable for almost any concrete requirement.

Standards activities related to concrete produced by VMCM equipment have been limited. However, in 1971, ASTM developed and now maintains ASTM C 685, "Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing."

CHAPTER 2—EQUIPMENT

2.1—Materials storage and measurement

Measurement of material by volume can be accomplished by a variety of means. Rotary vane feeders (both horizontal and vertical axis), screw conveyors (both adjustable and fixed speed), drag chains, calibrated gate openings, variable-volume sliding compartments, and vibrating plate feeders all have been used to measure quantities of dry ingredients. Liquids may be introduced by air pressure, pumps, or cylinders with the flow controlled by valves or timers and measured by flow meters. Readers are directed to the documents produced by the equipment manufacturers for operating details of the various types of equipment. Cement, water, and admixtures are stored in separate containers and measured separately. Fine and coarse aggregates are stored either separately or combined. If aggregates are stored and used in a combined state, they must be accurately preblended, and particular care must be taken to avoid segregation.

In presently available equipment, a meter records the rate of introduction of cement into the mixture and this rate serves, directly or indirectly, to control the rate at which other ingredients are added. All systems are interconnected so that, once they are calibrated and set to produce a specific concrete mixture, all ingredients are simultaneously and continuously measured into the mixer. This interconnecting allows either continuous or intermittent operation of the system to accommodate the quantities of the concrete needed. These interconnections should not be confused with the interlocks typically found in weigh-type batch plants. VMCM equipment is designed to allow the relative proportions of ingredients to be changed rapidly to vary the concrete mixture as required. Because the mixing chamber only holds about 2 ft^3, such changes can be made with little or no waste.

Typical VMCM units carry enough materials to produce 6 to 10 yd^3 of concrete (Fig. 2.1). This limitation is based upon axle loading limitations. Production of larger volumes of concrete or high rates of production will require special provisions for recharging the material storage compartments.

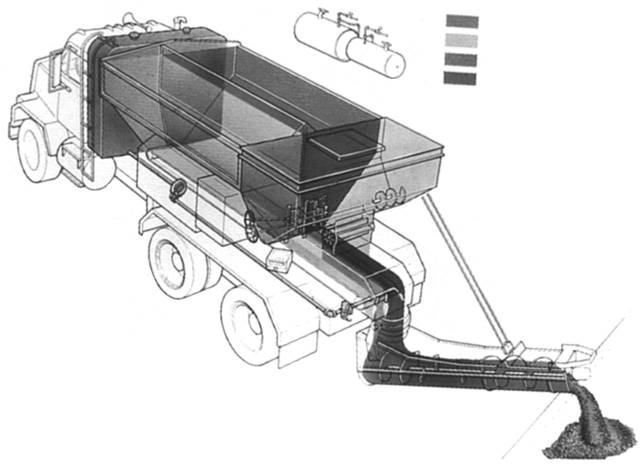

Fig. 2.1—Typical system.

2.2—Mixers

For mixing, most of the present continuous mixers utilize an auger rotated in a sloped trough or tube. Materials are introduced at or near the lower end, and the mixed concrete is discharged at the other. This basic principle is the same for all VMCM equipment, although there are many individual variations. Augers are available in different lengths and diameters and operate at different speeds and may have continuous or interrupted flighting. Troughs may have flexible or rigid bottoms and covered or open tops. The slope of the mixer may be fixed or adjustable. Lowering the trough (they are normally set at about 15 degrees) will reduce the mixing time, while raising the trough will extend it. A pivot at the base of most mixers allows them to swing from side to side.

With this type of mixer, output is always equal to input, with a relatively small amount of material being mixed at anyone time. Thorough mixing is accomplished in a very short time by applying high-shear, high-energy mixing to the material. Actual mixing time from input to output is usually less than 20 seconds. Production capability of the unit is more dependent on the supply of materials than on the type or capacity of the mixer.

2.3—Equipment condition

All proportioning and mixing equipment should be well maintained in accordance with the manufacturer's instructions. This point cannot be overemphasized. The finished product is probably the best test of equipment condition.

There are certain areas to which particular attention should be paid. The cement dispenser must be clean and free of any buildup. Valves must operate smoothly and not leak. Any accumulation of materials on any controlling surface or opening in the system will alter the calibrated flow of materials. Mixer augers should not be allowed to wear beyond the manufacturer's recommended limits. There should be no buildup of concrete on the mixer-auger surfaces. Belts must be properly adjusted and kept in good repair. There should be no leaks in the hydraulic or air systems. There should be no cut or damaged insulation on electric wires. All covers and guards should be securely in place.

CHAPTER 3—OPERATIONS

3.1—General

Volumetric measurement and continuous mixing are suitable for producing almost any concrete with appropriately sized aggregate, provided the equipment is operated with the same attention to detail as would be required to produce concrete by any other means. Most of the present equipment is truck- or trailer-mounted, or at least portable, and typically serves as its own material transport. The portability of the equipment makes it practical to bring the VMCM unit to the point of use, which can be an advantage in many applications. Having the unit at the placement site also allows close control of concrete quality at the site.

3.2—Production rates

Maximum production rates are dependent upon the physical and mechanical characteristics of the VMCM unit. Discharge rates for a cubic foot of cement (about 100 lb) range from about 48 to 28 seconds. For a concrete with a cement content of 564 lb/yd^3, these discharge rates imply production rates of about 12 to 21 yd^3/hour. However, these rates can only be achieved if the units are resupplied with materials during production.

3.3—Planning

A review should be made of the job requirements prior to concrete production. Depending on the application, this may be a review by the operator or a more detailed formal meeting among all parties involved. Review points should include discussion of the following items, which are further covered in Chapter 5:

1. Current calibration of materials being used.
2. Functional controls and settings proper for the job.
3. Production rates and delivery times.
4. Required testing requirements and methods.
5. Availability of testing equipment.
6. Adequate access on site for operation.

3.4—Materials

Ingredients that are used to calibrate the unit should be the same that will be used for production. All materials should be stored and handled in accordance with good concrete practices (ACI 304R). The moisture content of the fine aggregate must be carefully controlled to avoid undesirable variations in the mixture. Particular care should be taken during loading to avoid spilling materials into the wrong compartments. When moist aggregates are preloaded (6 to 8 hours in advance of production), the operator will need to reduce the initial water introduction slightly to maintain the proper slump and compensate for water that has drained to the bottom of the aggregates. Preloaded equipment should be stored inside or covered during inclement weather. Driving loaded equipment over rough roads may compact aggregates, causing errors in flow rates. If this occurs, recalibration may be necessary at the production site.

3.5—Personnel qualifications

It is essential that personnel responsible for control be knowledgeable in all phases of equipment use. Control of material proportions is direct and immediate; therefore, operators must also understand the significance of any adjustments made. This also places additional responsibilities on quality control personnel, as any change in the system could possibly adversely affect concrete quality and cost. Personnel involved in operating this type of equipment should have a thorough understanding of the controls and should be acquainted with concrete technology. Personnel authorized to make adjustments of the proportioning controls should have received training and/or certification from the equipment manufacturer or have at least 4 weeks of on-the-job training with qualified personnel.

CHAPTER 4—APPLICATION

4.1—General

VMCM equipment lends itself to many different applications. While many of these applications involve relatively low-volume production of concrete, large jobs have also been done with this equipment. In addition to producing conventional concrete, VMCM equipment is well suited for a variety of special applications (Fig. 4.1). Some of these applications are discussed in the following sections.

Fig. 4.1—Trailer-mounted unit modified to produce polymer concrete.

4.2—Mixtures with short working times

Concretes made with rapid-setting cements, special rapid-setting admixtures, or polymeric materials have a relatively short working life. Applications include repairs to hydraulic and highway structures and precast concrete products. Since VMCM equipment proportions and mixes at the job site, maximum possible working time is obtained.

4.3—Low-slump mixtures

A well-known application of this type is the low-slump Iowa DOT high-density overlay (Fig. 4.3.1). In this case, a 1 in. maximum slump is allowed and no additional water may be added to the concrete. Other applications include slipform placing (Fig. 4.3.2) and shotcrete mixtures. The efficient mixing action of the continuous mixer is capable of handling all of these applications.

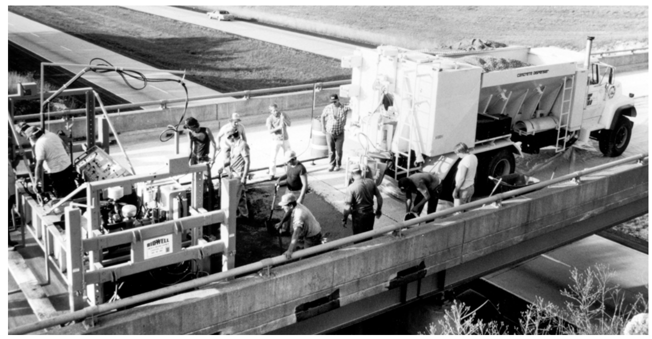

Fig. 4.3.1—Production of concrete for a low-slump bridge overlay with a VMCM unit.

Fig. 4.3.2—Slipforming a bridge parapet with concrete made by a VMCM.

4.4—Long unloading times

Some applications require relatively small amounts of concrete on a constant basis. Shotcrete and vertical slipforming are good examples. Changes in the concrete properties could occur if a large volume of concrete is held at the job site and discharged over a long period.

4.5—Concrete at remote sites

A VMCM unit is a complete proportioning and mixing system. It can be used as a plant at the job site, thereby eliminating long haul times for ready-mixed concrete (Fig. 4.5.1 and 4.5.2). In remote areas, this can be very cost effective from both a production and quality standpoint.

4.6—Making small deliveries

Small orders of ready-mixed concrete require individual trips for each order. These small orders can be consolidated into one trip with a VMCM unit. The unit can go out full and does not need to return until empty (Fig. 4.6).

4.7—Precast operations

VMCM units in precast plants can provide uninterrupted delivery throughout a large area with rapid control of consistency and workability. Waste can be significantly reduced when casting architectural panels, block, and molded items.

4.8—Hot weather concreting

The concrete is discharged as it is mixed; therefore, most hydration takes place after the discharge. The concrete can be in place in the forms very quickly after mixing so there is very little chance for the concrete to heat up after mixing, but before placing. No tempering water is required to maintain workability, therefore, the water-cement ratio can be controlled more easily.

Fig. 4.5.1—Transportable plant providing concrete directly and continuously to a concrete pump.

Fig. 4.5.2—Self-loading unit premixing concrete for delivery into an agitator truck.

4.9—Mining applications

Because of their compact size, VMCM units have been customized to fit into a mine shaft. Typically, these units have been reduced in height. Units also have been designed in components that bolt together so they could be reassembled in the mine after entering via a standard hoist.

4.10—Grouting and pile filling

These applications also often require small volumes of grout or concrete over an extended period. Both placement types require that a suitable material be available when the application is ready, and both may require indefinite volumes of material. Retempering may be required if large volumes of ready-mixed concrete or grout are held waiting at the job site.

4.11—Colored concretes

Many precast operations require colored concrete. The small mixing auger can be cleaned much more quickly and more thoroughly than batch-type mixers. The vigorous mixing action of the auger-type mixer thoroughly homogenizes the mixture for uniform coloring.

Fig. 4.6—VMCM unit supplying concrete for a residential foundation.

4.12—Emergency applications

VMCM units may be used as emergency sources of concrete to handle repair situations. A preloaded unit could be held in standby for emergency situations that arise when there is no other source of concrete.

CHAPTER 5—QUALITY CONCRETE AND TESTING

5.1—General

The production of concrete by volumetric measurement and continuous mixing is subject to the same rules of quality control as any other concrete production method. The equipment should be clean, well maintained, and operated by experienced personnel. ASTM C 685 (AASHTO M 241) is the standard specification for concrete made by these methods and is similar to ASTM C 94. As with any type of batching equipment, common sense, experienced personnel, and trained inspectors are the best quality assurance tools.

5.2—Calibration

To insure production of quality concrete, each volumetric-measuring unit must be calibrated for each respective concrete ingredient, following the manufacturer's recommendations and ASTM C 685. These ingredients must be the same as those to be used in actual concrete production. The measuring devices for aggregates, cement, and dry admixtures are calibrated by weighing the discharged ingredient. Devices for water, latex modifier (if required), and liquid admixtures such as air-entraining and water-reducing admixtures generally are calibrated by weighing or measuring the volume of the discharged ingredient. The objective of calibration is to coordinate the discharge of all concrete ingredients to produce the proper mixture.

A complete calibration procedure should be conducted: 1) for all new equipment; 2) when test data indicate that the concrete is not meeting specified performance levels; 3) when requested by the purchaser or engineer; or 4) when a change is made in materials or mixture proportions for which previous calibration data are unavailable. Complete calibrations should also be accomplished on a periodic basis depending upon intervening time since the unit was calibrated for another reason and the volume of concrete being produced.

An abbreviated calibration to verify cement discharge or a volumetric yield check will verify the accuracy of previous control settings. Such abbreviated calibrations are useful and economical when small quantities of concrete (under 50 yd^3) are to be produced using the same control settings with similar ingredients. Project specifications should clearly define concrete performance requirements, and equipment should be calibrated to meet those requirements.

The New York State Department of Transportation has developed a detailed method for calibrating VMCM units.[1] A copy of this calibration procedure is included as Appendix A to this report.

5.2.1 *Equipment required—The* following equipment is required to perform a full calibration: a scale with a minimum capacity of 300 lb, a clean container to catch cement and aggregate discharge, a container calibrated in fluid ounces to catch admixture discharge, a container to catch water or other liquid discharge, a stopwatch accurate to 1/10 of a second, and a container to check volumetric yield (normally a 1/4 yd^3 box). Tolerances as stated in ASTM C 685 are:

Cement, percent by weight	0 to +4
Fine aggregate, percent by weight	+/– 2
Coarse aggregate, percent by weight	+/– 2
Admixtures, percent by weight	+/– 3
Water, percent by weight	+/– 1

5.2.2 *Cement*—The cement discharge system is normally connected directly to the indicator used to determine concrete production quantity. This system also determines the rate at which all other discharge systems must provide materials to the mixer to produce the required mixture. It is necessary to establish the weight of cement discharged for a given register or counter reading as well as the amount discharged in a given time.

When calibrating cement, precautions should be taken to insure that the aggregate bins are empty (or separated from the system) and that all of the discharge is collected. Any carrying mechanisms for the cement should be primed by operating the system until any surface between the storage bin and the collection container which might attract cement becomes coated. The meter register or counter should then be reset to zero and a minimum of five calibration runs should be made. These runs should each use at least 94 lb of cement.

When calibrating rotary discharge systems, it is preferable to stop the run at a whole number of revolutions rather than attempt to stop at a fixed time or weight. At the conclusion of each run, the meter reading, time (in seconds), and the gross and tare weights are recorded. The net weight and weight per meter unit are then calculated. The weight of cement discharged in 1 minute is also calculated.

5.2.3 *Aggregates*—Aggregate discharge controls must be calibrated to provide the correct proportions in relation to the cement. This can be accomplished by establishing discharge rate in weight per unit time or weight per cement meter unit. The required weight of aggregate discharge for either of these units may be calculated and trials made at various control settings until the desired weight is collected. Aggregates must be calibrated individually. This method of trial and error is best used when working with a familiar mix design and similar aggregates.

When the system is being calibrated for several mixtures and with unfamiliar aggregates, it may be useful to plot the weight per unit time versus control settings for a minimum of five control settings. The graph developed can then be used to interpolate the required settings for the various concrete mixtures. Verification runs should be made after any such chart is developed.

5.2.4 *Water*—Normally, the control setting for the maximum permitted water is determined for a given time or meter unit on the cement register. The discharge is then collected and weighed or measured in a graduated container to verify the setting. The accuracy of flow meters (gal./min) and/or recording flow meters (total gal.), if present, should be verified at this time. For each calibration run, the system should be operated at least as long as the discharge time for 94 lb of cement.

Because there are fewer mechanical operating components involved with the water discharge than with the cement, fewer calibration runs will be necessary.

5.2.5 *Admixtures*—Wet or dry admixture discharge should be calibrated for indicated flow rate versus measured delivery. The flow of each admixture being calibrated should be caught in a calibrated receptacle for at least as long as the discharge time of 94 lb of cement. A chart of flow indicator position versus actual flow can be established. As many calibration runs as necessary to meet the specified tolerances should be made.

5.2.6 *Post-calibration volumetric-yield test*—All controls should be set to produce the desired mixture. All controls should be engaged and all systems charged. All controls should be stopped simultaneously and the meter register or counter reset. A container of known volume with rigid sides is then placed under the discharge of the mixer. All controls are then engaged simultaneously and the proper count is run on the meter register. The count is determined based on the known volume of the container; for example, 1/4 of the l-yd count should be used with a 1/4 yd^3 container (Fig. 5.2.6).

Another method for a yield check by weighting is detailed in ASTM C 685.

5.2.7 *Preproduction tests*—After calibration, preproduction tests may be made to confirm whether the production mixture proportions meet the requirements of the laboratory mixture proportions and provide a reference for production testing. The following minimum tests should be made at this time: air content (ASTM C 231 or C 173), slump (ASTM C 143), and unit weight (ASTM C 138). It is also advisable to cast cylinders for compressive strength testing at this time.

5.3—Production testing

Parameters for testing should be established to meet job-site requirements. Generally, testing for concrete produced using VMCM equipment should follow the same guidelines as for concrete produced by other methods. Suggested tests include: air content (ASTM C 173 or C 231), slump (ASTM C 143), and unit weight (ASTM C 138). Project specifications should include the frequency interval for these tests.

Fig. 5.2.6—Volumetric yield test.

This frequency may vary from one set of tests per unit per cubic yard to one set for each load. As with weigh-batched concrete, these tests serve as a quick check for quality control.

It is also good practice to perform a volumetric-yield test on each mixer at least once per day or at intervals of at least 50 yd^3 of production. The concrete produced for this yield test can often be incorporated directly into the work. The previously mentioned air, slump, and unit weight tests should also be made at this time. Cylinders or beams for strength tests should be cast from concrete obtained at point of discharge at the same time as the other testing. Any other suitable tests may be used at the discretion of the specifier; however, experience and economics dictate that such testing need not be more stringent than that required for weigh-batched concrete.

CHAPTER 6—OPERATIONAL PRECAUTIONS

6.1—General

The volumetric-measurement and continuous-mixing equipment should be in good condition. All shields and covers should be in place. All controls should operate smoothly and be connected according to the manufacturer's recommendations. All material-feed operations must start and stop simultaneously. The cement-measuring device must be inspected and cleaned regularly. Indicating meters and dials should be operational and readable. Admixture systems should be ·checked for proper flow and operation. All filters should be clean and allow full flow of water. Aggregate feed systems should be free of any blockage. Checks of the various feeding systems should be carried out according to the manufacturer's recommendations and as job experience indicates.

6.2—Cold weather concrete

All aggregates must be free of frozen material, as frozen lumps may affect the metering accuracy. All liquid lines must be protected from freezing and drained when not in use. Flow meters must be checked for proper operation and protected from damage by freezing liquids. Additional information on cold weather concreting may be found in ACI 306R.

6.3—Hot weather concrete

Using VMCM under hot weather concreting conditions is not greatly different from conventional concrete practice. The general principles as outlined by ACI Committee 305 for maintaining concrete temperatures below specified limits will still apply.

6.4—Aggregate moisture

Since proportioning is done on a continuous basis, it is desirable to supply the machine with aggregates of a uniform moisture content. Bulking of fine aggregate is not normally a consideration because the usual moisture content covers a small range where bulking is fairly constant. A yield check is recommended when there is a wide swing in moisture content (2% or more). This check will indicate if recalibration is required. Aggregate stockpiles being used to charge VMCM units should be covered to minimize variations in moisture content. It may be necessary to limit the free moisture in aggregate by drying and/or covering to meet the low *w/c* requirements when high volumes of liquid additives, such as latex, are used.

6.5—Rapid slump loss

It has been noted that, with some cements, a rapid slump loss occurs after discharge from the mixer (ACI 225R). The cause is believed to be related to the short mixing time typical with this type of equipment. The problem does not occur often, and a change of cement will normally correct it.

6.6—Use of admixtures

Continuous mixers are high-shear, high-speed mixers. Some admixtures perform differently than might be expected when used with conventional mixers. For this reason, the performance of admixtures should be verified by testing for the desired result before actual project placement begins. Experience has shown that these results will remain consistent once the desired result has been verified on a particular piece of equipment. If deemed necessary to improve the performance of an admixture, a limited increase in mixing time may be achieved by increasing the angle of the mixing equipment.

6.7—Fresh concrete properties

Fresh concrete produced by VMCM equipment behaves slightly differently than ready-mixed concrete. Elapsed hydration time at discharge is measured in seconds rather than in minutes. This means that, while the actual setting time (from start of hydration) is the same, the apparent setting time (from time in place) may seem longer. Finally, the apparent slump at discharge is often higher than the measured slump 3 to 5 minutes after discharge. Finishers and inspectors should be made aware of these differences.

CHAPTER 7—REFERENCES

7.1—Specified and/or recommended references

The documents of the various standards-producing organizations referred to in this document are listed below with their serial designations.

American Association of State Highway and Transportation Officials

M 241-86 Concrete Made by Volumetric Batching and Continuous Mixing

American Concrete Institute

225R Guide to the Selection and Use of Hydraulic Cements

304R Guide for Measuring, Mixing, Transporting, and Placing Concrete

305R Hot Weather Concreting

306R Cold Weather Concreting

ASTM International

C 94 Standard Specification for Ready-Mixed Concrete

C 138 Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete

C 143 Standard Test Method for Slump of Portland Cement Concrete

C 173 Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 231 Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 685 Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

The preceding publications may be obtained from the following organizations:

American Association of State Highway and Transportation Officials
444 N. Capitol Street NW, Suite 225
Washington, DC 20001

American Concrete Institute
P.O. Box 9094
Farmington Hills, MI 48333-9094

ASTM International
100 Barr Harbor Dr.
West Conshohocken, PA 19428-2959

7.2—Cited references

1. "Calibration of Mobile Mixers (Concrete Mobiles) to Produce Portland Cement Concrete," *Material Method* NY 9.4, New York State Department of Transportation, Albany, N.Y., 8 pp.

This report was submitted to letter ballot of the committee and approved in accordance with ACI balloting procedures.

APPENDIX A

NEW YORK STATE DEPARTMENT OF TRANSPORTATION MATERIALS BUREAU ALBANY, NY 12232 MATERIALS METHOD	MATERIALS METHOD - NY 9.4 ISSUE DATE - May, 1979
CALIBRATION OF MOBILE MIXERS (CONCRETE-MOBILES) TO PRODUCE PORTLAND CEMENT CONCRETE	
Approved By James J. Murphy JAMES J. MURPHY DIRECTOR, MATERIALS BUREAU	MAP CODE 7.42-1-9.4

SCOPE

This method prescribes the procedure to be followed when checking the calibration of the mobile mixers to produce portland cement concrete. The purpose for calibration is to set the controls of the mobile mixers, using materials proposed for the particular job, so that it produces a cubic yard of portland cement concrete containing those relative quantities established in a mix design.

Each mobile mixing unit shall be inspected and approved by the Engineer. If in the opinon of the Engineer, improper conditions exist, the conditions shall be corrected to the satisfaction of the Engineer, or the mixer shall be replaced. Improper conditions shall include, but not be limited to, hydrated cement deposits and mixing paddles which are loose, broken, bent scalloped, worn 20 percent in any dimension, or heavily caked with mortar.

Each mobile mixing unit shall be calibrated by the contractor and checked by the Engineer initially using project materials to set the controls so that materials are proportioned to those relative quantities established in the project mix design. After this initial calibration, additional full or partial calibrations may be required by the engineer as follows: whenever major maintenance operations occur in the mobile mixing unit, whenever the unit leaves and returns to the job site, or whenever material proportioning becomes suspect.

CALIBRATION PROCEDURES

A. PRECALIBRATION CHECKS

In order for the mobile mixing unit to batch accurately several key points, listed in the current edition of the Concrete-Mobile Handbook found under "Mechanical Factors that affect concrete produced by a Concrete Mobile Unit", must be periodically checked.

A few of these key points are listed below:

1. Check cleanliness of cement bin. The bin must be dry and free of any hardened cement. The cross auger must be clean and the steel fingers welded to it must all be in place and straight. The aerators must be operative and the vent must be open and free of debris.

2. Check ground strap. Unit must be properly grounded to prevent cement from clinging to sides of bins due to static electricity accumulation.

Manual Materials Method, NY 9.4	Code 7.42-1-9.4 Date May, 1979	Page 2
Subject: Calibration Of Mobile Mixers (Concrete-Mobiles) To Produce Portland Cement Concrete		

3. Check cleanliness of cement meter-feeder. The pockets in the meter drum must be free from any cement buildup; and the hammers at the end of the spring tines should be properly striking the meter drum as it rotates.

4. Check the cement meter register for proper operating condition. The drive cable should be tight and free from kinks.

5. Check the main conveyor belt for cleanliness and tension. The belt shall not show excessive sag.

6. Check all the bin vibrators for proper working order.

7. Check the operational speed specification (RPM). In order to achieve uniform flow of materials, it is essential to maintain consistent operational speed within the designed operational speed range for the unit. Mechanical units have a tachometer for monitoring operational speed. If the unit is functioning properly the following tachometer (RPM) readings should result in the proper operational speed.

UNIT	TACH. (RPM)
Serial #'s 708 and lower	1250
Serial #'s 709 and higher	1670
Magnum	2250

Hydraulic units are not equipped with tachometers. The operating speed of these units should be checked by timing the main conveyor belt drive shaft. The main conveyor belt drive shaft should operate between 39 to 43 revolutions per minute. The only exception being the newly developed Model #60 Concrete-Mobile; this should operate at 56 RPM. A secondary check on operating speed is the cement meter counter, it should operate at a rate of 142 counts per minute.

B. CEMENT CALIBRATION

1. Aggregate bins must be empty and clean.

2. Charge the cement hopper with at least 36 bags or 3400 pounds of the same type and brand of cement to be used on project. Continuous feeding of cement is not permitted.

3. Prime the conveyor belt with cement for its entire length. Bypass the mix auger by leaving it in the travel position. Run out at least two bags of cement. It is not necessary to weigh this sample.

4. Obtain the cement container tare weight to nearest 0.5 pound. This tare weight shall be determined prior to taking each cement sample.

Manual: Materials Method, NY 9.4	Code 7.42-1-9.4	Date May, 1979	Page 3
Subject: Calibration Of Mobile Mixers (Concrete-Mobiles) To Produce Portland Cement Concrete			

5. Reset the cement meter counter to zero.

6. Set the mixing unit at the proper operating speed and obtain cement samples to determine the exact time (to nearest 0.1 second) and meter count (to nearest 0.5 count) required to discharge one bag plus 2% by weight or 96 pounds of portland cement.*

   either by (a) Trial and error, or

   (b) Averaging 5 two bag samples or 10 one bag samples

*The additional 2% cement is to allow for a 0 to +4 percent tolerance on cement delivery, which is consistent with ASTM and manufacturers guidelines.

(a) Trial and Error. Obtain and record cement weights for several meter counts, and discharge times to determine the cement meter count and discharge time that delivers 96 pounds of cement. Record this data on the cement calibration worksheet; if additional space is required, use back of worksheet. Using this established count and time obtain three additional samples and record each weight. These cement samples must meet the following tolerance: 96 pounds ± 2%.

NOTE: If the cement samples do not meet the 2% tolerance, take three additional samples to recheck delivery tolerance. If these results also fall outside the 2% tolerance, the unit shall not be acceptable for project use.

(b-1) Averaging 5 two bag samples. Obtain five cement samples of approximately 2 bag size (188 Pounds). Record the cement weight, meter count and discharge time on the Cement Calibration Worksheet. Compute the cement meter count and discharge time to deliver 96 pounds of cement. Steps 2 thru 5 of the worksheet detail the computation procedure. Using the established count and time obtain one additional sample to check computation accuracy. Record this sample on worksheet in space provided for Check Run. This sample must be within ± 2% of the desired 96 pounds.

NOTE: If the cement sample does not meet the 2% tolerance, check for error in mathematical computations. If no errors are found repeat the calibration procedure. If retest also fails, the unit shall not be acceptable for project use.

(b-2) Averaging 10 one bag samples. Obtain ten cement samples of approximately 1 bag size (94 pounds). Record the cement weight, meter count and discharge time on the Cement Calibration Worksheet. Compute the cement meter count and discharge time to deliver 96 pounds of cement. Steps 2 thru 5 of the worksheet detail the computation procedure. Using the established count and time obtain one additional sample to check computation accuracy. Record this sample on worksheet in space provided for Check Run. This sample must be within ± 2% of the desired 96 pounds.

Manual: Materials Method, NY 9.4	Code 7.42-1-9.4	Date May, 1979	Page 4
Subject: Calibration of Mobile Mixers (Concrete-Mobiles) To Produce Portland Cement Concrete			

NOTE: If the cement sample does not meet the 2% tolerance, check for error in mathematical computations. If no errors are found, repeat the above procedure. If the retest also fails, the unit shall not be acceptable for project use.

ALL REMAINING INGREDIENTS ARE CALIBRATED TO THE TIME CYCLE OR CEMENT METER FEEDER COUNT ESTABLISHED ABOVE. WHEN THE MOBILE-MIXING UNIT IS EQUIPPED WITH A CEMENT METER-FEEDER BYPASS SHAFT, THE COUNT MODE MAY BE USED.

C. FINE AND COARSE AGGREGATE CALIBRATION

1. Obtain the mix design proportions based on a one bag mix. These can be obtained from your Materials Engineer.

2. Obtain the Fine and Coarse Aggregate Absorption percentages from either the NYSDOT Approved source listing or Regional Materials Engineer.

3. Determine the Fine and Coarse Aggregate oven dry moisture content at the stockpiles immediately prior to calibration. This may be done prior to the cement calibration if deemed necessary.

4. Calculate the Project Fine and Coarse Aggregate Weights (per 1 bag mix) as follows:

$$\text{PROJ. AGG. WGT.} = \frac{\text{1 Bag Agg. Mix Design Wgt. (SSD)}}{1-\left(\frac{\text{Moist. (\%)} - \text{Abs. (\%)}}{100}\right)}$$

NOTE: Results to nearest 0.5 pound.

5. Using project aggregates load either the coarse or fine aggregate bin at least 2/3 full. (Note - Only the bin being calibrated shall have material in it. If the rubber divider is deflected toward one bin, fill the bin that the rubber divider projects into first so as to prevent flow of material into the adjacent bin).

6. Disengage the cement discharge mechanism.

7. Prime the conveyor belt with aggregate for its entire length. This is to be done each time the gate setting is changed.

   NOTE: At this time, note flow pattern of aggregate at the end of the conveyor belt. An overflow may occur due to deformation of the rubber divider at the bottom of the bin separator. If overflow is present stop it by either adjusting or changing the rubber divider. If the overflow still occurs, the divider can be restrained by blocking with lumber or similar material on the empty side of the bin divider.

8. Set the mixing unit at the proper operating speed.

Manual Materials Method, NY 9.4	Code 7.42-1-9.4 Date May, 1979 Page 5
Subject: Calibration of Mobile Mixers (Concrete-Mobiles) To Produce Portland Cement Concrete	

9. Using either the time cycle or cement meter count established in the cement calibration, vary the aggregate gate settings to establish a setting that discharges the project aggregate weight (Step 4). Record this data on the aggregate calibration worksheet.

10. After establishing the gate setting run at least three more samples at this gate setting. For the aggregate discharge system to be acceptable:

(a) The average of the three samples must be within ± 2% of the calculated project aggregate weight <u>and</u>

(b) Each sample must be within ± 2% of the average.

11. Upon completion completely clean the aggregate bins and conveyor belt and determine the gate setting for the remaining aggregate by following the same procedure as stated previously; or rather than emptying the initial aggregate bin, set its gate in the closed position. A slight overflow of material may result when running with the gate closed. Determine this amount of material before loading the other bin by operating the conveyor belt at the proper operating speed and for the time cycle determined to deliver 1 bag of cement, measure and record the actual overflow. This should be a very small amount of material, approximately 3 to 5 pounds. The measured overflow should be taken into account by taring out when calibrating the remaining aggregate gate setting.

D. <u>WATER CALIBRATION</u>

The total water content in the concrete mix is controlled indirectly, by concrete slump values, because of variation in aggregate moisture content. However, it is essential that the water delivery system discharge a constant rate of water so that excessive slump variations do not occur.

These mobile mixers batch water volumetrically through flowmeters which monitor the water flow rate in gallons per minute. The water delivery system, including flowmeter, shall be checked for repeatability of water flow rate as follows:

1. Fill the water tank (when water reducing admixtures are added directly to the water system, it need not be added for the calibration; however it must be added for the yield test).

2. Obtain the water container tare weight to nearest 0.1 pound. (Container shall hold at least 5 gal.).

3. Set the mixing unit at the proper operating speed.

4. Prime the water system by allowing water to flow out for approximately 15 seconds.

5. Set the flowmeter to discharge approximately 5 gal./min. Obtain sample by interrupting water flow and record the discharge time (to nearest 0.1 second) to approximately fill the 5 gallon container. Weigh this amount of water and subtract tare weight of container to obtain the actual weight of water.

Manual Materials Method, NY 9.4	Code 7.42-1-9.4 Date May, 1979 Page 6
Subject: Calibration Of Mobile Mixers (Concrete-Mobiles) To Produce Portland Cement Concrete	

6. Repeat the above procedure at least 2 more times at the same flowmeter setting and discharge time. If each individual test has no more than ± 2% variation from the average weight, the unit water discharge system is acceptable.

E. <u>ADMIXTURE INJECTION SYSTEM CALIBRATION</u>

These systems provide a means of injecting predetermined amounts of admixture in solution into the concrete mix. In order for the affected concrete properties to be uniformly maintained these systems must deliver material quantities consistently and repeatedly. Admixtures are batched volumetrically and flowmeters are used to monitor batching quantities. These systems should be calibrated as follows:

1. Calculate admixture solution flow rate for (1) LO-FLOW and (2) HI-FLOW systems as follows:

(1)
LO-FLOW: $\text{FLOW RATE (oz/min)} = \dfrac{60\text{ (sec/min)} \times \text{Dosage Rate (oz/bag)} \times 6\text{ (part sol.)}}{\text{Cement Discharge Time (sec/bag)}}$

(2)
HI-FLOW: $\text{FLOW RATE (qt/min)} = \dfrac{60\text{ (sec/min)} \times \text{Dosage Rate (oz/bag)} \times 10\text{ (part sol.)}}{\text{Cement Discharge Time (sec/bag)} \times 32\text{ (oz/qt)}}$

2. Fill the admixture systems with the proper part solutions to be used on the job. Plain water may be used for calibration, however, the correct solutions must be used for the yield test.

3. Set the air pressure regulator gauge at 15 psi for standard units or 25 psi for magnum units.

4. Using a calibrated vial, either ounces or milliliters (29.5 ml = 1 oz.), and a discharge time of <u>one</u> minute, establish a <u>flowmeter setting</u> that will deliver the calculated flow rate (step 1). If a <u>Concrete-Mobile Handbook</u> is available the Flowmeter Diagrams for LO-FLOW systems (pg. 44, 45, or 46) or HI-FLOW systems (pg. 38 or 39) can be used to obtain an initial flowmeter setting.

NOTE - The flowmeter setting should be within the working range of the scale to allow for adjustments due to variations in the field air content. The <u>part solution</u> may be changed to accomplish this.

5. Having established a flowmeter setting, obtain three (3) <u>one</u> minute samples and record each volume. If each individual test has no more than ± 3% variation from the average flow rate, the unit admixture system is acceptable.

F. <u>LATEX CALIBRATION</u>

Latex is batched volumetrically through flowmeters which monitor batching quantities in <u>GALLONS PER MINUTE</u>. The latex delivery system is essentially the same as the water delivery system and should be calibrated to accurately deliver 3.5 gallons of latex per bag of cement as follows:

Manual: Materials Method, NY 9.4	Code 7.42-1-9.4 Date May, 1979 Page 7
Subject: Calibration Of Mobile Mixers (Concrete-Mobiles) To Produce Portland Cement Concrete	

1. Calculate the Latex Flow Rate in gal/min as follows:

   $$\text{FLOW RATE (gal/min)} = \frac{60\text{ (sec/min)} \times 3.5\text{ (gal/bag, latex dosage rate)}}{\text{Cement Discharge Time (sec/bag)}}$$

2. Obtain the latex container tare weight to nearest 0.1 pound. The container shall have a minimum capacity of five gallons.

3. Fill the holding tank with latex and set the mixing unit at the proper operating speed.

4. Prime the latex system by allowing latex to flow out for approximately 15 seconds.

5. Set the flowmeter at the calculated flow rate (step 1) and record discharge time (to nearest 0.1 second) to approximately fill the 5 gallon container. Weigh this amount of latex and subtract tare weight of container to obtain the actual weight of latex. Using the same time, obtain two (2) more samples of latex, and calculate an average weight.

6. The latex system is acceptable if the following repeatability (1) and accuracy.(2) criteria are met:

   (1) If each individual test has no more than ± 1% variation from the average weight and

   (2) The average flow rate is within ± 1% of the calculated flow rate (step 1). Average flow rate is calculated as follows:

   $$\text{AVG. FLOW RATE (gal/min)} = \frac{\text{Avg. Sample Wgt. (lbs)} \times 60\text{ (sec/min)}}{8.5\text{ (lbs/gal)} \times \text{Latex Sample Discharge Time (sec)}}$$

G. YIELD TEST

After establishing and checking the various settings that control batching quantities of all ingredients as outlined in the calibration steps, it is necessary to check the yield of the integrated mixing system to insure that the proportions set in the mix design actually produce a cubic yard of portland cement concrete.

Steps that should be followed to perform the yield test are:

1. Fill the mixing unit with project materials, including admixtures.

2. Check all gate, valve, and flowmeter settings for conformance with those established in the calibration steps.

3. Determine the Cement Meter Count to deliver a 1/4 cubic yard of concrete as follows:

   $$\text{1/4 C.Y. CEMENT COUNT} = \frac{\text{(One Bag Cement Count)} \times \text{(Mix Design Bags per C.Y.)}}{4}$$

Manual: Materials Method, NY 9.4	Code 7.42-1-9.4 Date May, 1979 Page 8
Subject: Calibration Of Mobile Mixers (Concrete-Mobiles) To Produce Portland Cement Concrete	

4. Place a 1/4 cubic yard box (36"x36"x9") beneath the mix conveyor to catch all the concrete discharged by the unit. Be sure that 1/4 yard box is rigid, level, clean, and well supported.

5. Set the mix conveyor at an angle of at least 15°, and swing it to the side so concrete will not discharge into the box.

6. Set unit at proper operating speed and discharge sufficient concrete to perform slump, air content, and unit weight tests.

   NOTE - Stop the mixing action and main conveyor simultaneously.

7. After achieving specified slump and air content restart unit and discharge until fresh concrete is produced. Stop mix conveyor and main conveyor simultaneously and reset the cement meter register to "0".

8. Swing the mix conveyor over the 1/4 yard box. Engage the mix conveyor and the main conveyor simultaneously to discharge concrete until the meter count equals that for a 1/4 yard or the box becomes full. Be sure to consolidate the concrete with mechanical vibratory equipment during and immediately after filling the box.

9. Strike-off the concrete in box and record the exact count. If box is not completely full, re-engage the unit simultaneously to discharge small quantities of concrete and record the exact count needed to fill the container. The count must be within ± 2% of the count calculated in Step 3 for the system to be acceptable.

   NOTE - Concrete yield is directly proportional to the air content of the concrete. In order for a concrete mix to achieve 100 percent yield the air content must be identical to that specified. Any deviation found in the actual air content (Step 6) with that specified must be taken into account when checking yield tolerance. (See worksheet.)

Sheet 1 of 5

BR 19-1 (4/79)

MOBILE CONCRETE UNIT

PORTLAND CEMENT CALIBRATION WORKSHEET

REGION 8 CONTRACT D 95000 DATE 5/15/79 MOBILE UNIT SERIAL NO. 8CM1394/24F

CERTIFIED CEMENT METER COUNT 71 CERTIFIED CEMENT DISCHARGE TIME 30

CEMENT CALIBRATION BY: ✓

(a) Trial and Error (b-1) Averaging Five 2 Bag Samples (b-2) Averaging Ten 1 Bag Samples

STEP 1: Record test data below: count nearest 0.5 count, time nearest 0.1 sec. and cement wgt. nearest 0.5 pound.

	Run Numbers											
	1	2	3	4	5	6	7	8	9	10	Total	Check Run
Meter Count	68.0	68.0	64.5	66.0	66.5	67.0	68.0	68.0	69.0	69.0	674	66.5
Disch. Time	29.5	29.5	27.5	28.5	29.0	29.2	29.7	29.5	30.0	30.0	292.4	29.0
Cement Wgt.	100.0	100.0	93.0	94.5	97.0	97.5	96.5	96.5	98.5	98.0	971.5	96.5 OK

Steps 2 thru 5 apply only when using averaging (b-1) or (b-2) methods to obtain project cement count and time.

Calculate project cement meter count as follows:

STEP 2: 674 (total counts (step 1)) ÷ 971.5 (total wgt. (step 1)) = 0.6938 count/pound (factor to 4 decimals)

STEP 3: 0.6938 (count/pound) x 96 = **66.5** Project cement meter count (nearest 0.5 count)

Calculate project cement discharge time as follows:

STEP 4: 292.4 (total time (step 1)) ÷ 971.5 (total wgt. (step 1)) = 0.3010 sec/pound (factor to 4 decimals)

STEP 5: 0.3010 (sec/pound) x 96 = **28.9** Project cement discharge time (nearest 0.1 sec)

NOTE: Ninety-Six (96) pounds is used to determine meter count and discharge time to deliver one bag or ninety-four (94) pounds of cement. This is done to result in a 0 to +4 percent tolerance on cement delivery, which is consistent with ASTM and manufacture's guidelines.

Sheet 2 of 5

BR 19-2 (4/79)

MOBILE CONCRETE UNIT

FINE ✓ ; COARSE AGGREGATE CALIBRATION WORKSHEET

REGION 8 , CONTRACT D 95000

MOBILE UNIT SERIAL NO. 8CM 1394/24F

PROJECT CEMENT METER COUNT 66.5 , PROJECT CEMENT DISCHARGE TIME 28.9

STEP 1: Project Aggregate Weight Computation:

$$\text{PROJECT AGGREGATE WEIGHT} = \frac{A}{1-\left(\frac{B}{100}\right)} = 158.1 \text{ pounds}$$

where:

A = Fine or Coarse Aggregate (SSD) Mix Design Weight per One Bag of Portland Cement. = 155.4 pounds

B = Aggregate Free Water Content [Total Moisture Content (%) Minus Aggregate Absorption (%)] = 1.7 %
[3.8 - 2.1 = 1.7]

STEP 2: Aggregate Gate Setting Determination by Trial and Error

Record the aggregate weights and aggregate gate settings, run for the time or cement meter count required to discharge one bag (94 lbs.) of cement, to determine the gate setting that delivers the project aggregate weight calculated above.

	RUN #1	RUN #2	RUN #3	RUN #4	RUN #5	RUN #6	RUN #7	RUN #8
Gate Setting	3.0	[illegible]	3.4					
Weight (Lbs.)	134.0	159.0	153.5					

STEP 3: Aggregate Batching Precision

After determining the gate setting (Step 2) that delivers the Project Aggregate Weight (Step 1) obtain three (3) more samples at that gate setting to determine batching precision.

PROJECT GATE SETTING (STEP 2) = **3.5**

	RUN #1	RUN #2	RUN #3
Sample Weight	160.0	161.5	161.0

$\bar{x} = 160.8$

The mobil unit's aggregate discharge system must meet the following criteria:

OK (1) The average of the three samples (Step 3) must be within ± 2% of the calculated Project Aggregate Weight (Step 1) and

OK (2) Each of the three samples must be within ± 2% of their average weight.

Sheet 3 of 5

BR 19-3 (4/79)

MOBILE CONCRETE UNIT

FINE ; COARSE ✓ AGGREGATE CALIBRATION WORKSHEET

REGION 8 , CONTRACT D 95000

MOBILE UNIT SERIAL NO. 8CM 1394/24F

PROJECT CEMENT METER COUNT 66.5 , PROJECT CEMENT DISCHARGE TIME 28.9

STEP 1: Project Aggregate Weight Computation:

$$\text{PROJECT AGGREGATE WEIGHT} = \frac{A}{1-\left(\frac{B}{100}\right)} = 163.3 \text{ pounds}$$

where:

A = Fine or Coarse Aggregate (SSD) Mix Design Weight per One Bag of Portland Cement. = 163.1 pounds

B = Aggregate Free Water Content [Total Moisture Content (%) Minus Aggregate Absorption (%)] = 0.1 %
[0.6 - 0.5 = 0.1]

STEP 2: Aggregate Gate Setting Determination by Trial and Error

Record the aggregate weights and aggregate gate settings, run for the time or cement meter count required to discharge one bag (94 lbs.) of cement, to determine the gate setting that delivers the project aggregate weight calculate above.

	RUN #1	RUN #2	RUN #3	RUN #4	RUN #5	RUN #6	RUN #7	RUN #8
Gate Setting	3.0	3.5	3.7	3.8				
Weight (Lbs.)	116.0	149.5	160.5	164.0				

STEP 3: Aggregate Batching Precision

After determining the gate setting (Step 2) that delivers the Project Aggregate Weight (Step 1) obtain three (3) more samples at that gate setting to determine batching precision.

PROJECT GATE SETTING (STEP 2) = **3.8**

	RUN #1	RUN #2	RUN #3
Sample Weight	164.0	165.5	165.5

$\bar{x} = 165.0$

The mobil unit's aggregate discharge system must meet the following criteria:

OK (1) The average of the three samples (Step 3) must be within ± 2% of the calculated Project Aggregate Weight (Step 1) and

OK (2) Each of the three samples must be within ± 2% of their average weight.

Sheet 4 of 5

BR 19-4 (4/79)

MOBILE CONCRETE UNIT

WATER, ADMIXTURE, AND LATEX CALIBRATION WORKSHEET

REGION 8 CONTRACT D 95000 DATE 5/15/79 MOBILE UNIT SERIAL NO. 8CM 1394/24F

WATER CALIBRATION

WATER FLOWMETER SETTING 5.0 G.P.M.; SAMPLE DISCHARGE TIME 50 SEC.

	Sample Number		
	1	2	3
Sample Weight	41.3	41.6	41.4

In order for the water system to be acceptable each sample must have no more than ± 2% variation from their average. OK

ADMIXTURE INJECTION SYSTEM CALIBRATION
(one minute samples)

LO-FLO SETTING ______ HI-FLO SETTING 1.5

	Sample Number		
	1	2	3
Sample Volume			

	Sample Number		
	1	2	3
Sample Volume	1200	1180	1210 ml.

In order for the admixture systems to be acceptable each sample must have no more than ± 3% variation from their average. OK

LATEX CALIBRATION

STEP 1: Latex Flow Rate Calculation:

Flow Rate G.P.M. = 60 (sec/min) x 3.5 gal.-latex dosage rate per bag / Cement Discharge Time (sec/bag) = ______ G.P.M.

STEP 2: Latex sampling - Flowmeter should be set to the flow-rate calculated above.

	Sample Number		
	1	2	3
Sample Weight			

The latex system is acceptable if the following repeatability (1) and accuracy (2) criteria are met:

(1) Each individual sample has no more than ± 2% variation from their average and
(2) The average flow rate is within ± 2% of the calculated flow rate (step 1). Average flow rate is calculated as follows:

AVG. FLOW RATE (G.P.M.) = Average Wgt. (pounds) x 60 (sec/min) / 8.50 (pounds/gal) x Latex Discharge Time (sec)

Sheet 5 of 5

BR 19-5 (4/79)

MOBILE CONCRETE UNIT

YIELD TEST WORKSHEET

REGION 8 CONTRACT D 95000 TESTING DATE 5/15/79

MOBILE UNIT SERIAL NO. 8CM 1394/24F

MATERIAL SETTINGS:

Aggregate: Sand 3.5

Stone 3.8

Admixture: Lo Flow ______ Part Solution ______

Hi Flow 1.5 Part Solution 10

Water Flow Meter 6.8 GPM

Latex Flow Meter ______ GPM

Project Cement Meter Count (Per bag of cement) 66.5

CONCRETE TEST RESULTS:

Air 5.8 %

Slump 1/2 inches

Unit Weight 143.6 lbs/cu. ft.

Step 1: Compute theoretical cement meter count per 1/4 cubic yard

Count per 1/4 c.y. = 66.5 (Project Cement Meter Count per bag) x 8.79 (Mix Design bags per c.y.) x 0.25 = 146.1

Step 2: Actual cement meter count to fill 1/4 cubic yard box = 148

Step 3: Actual count (step 2) corrected to 6.0% air content

CORRECTED CEMENT METER COUNT = Actual Count (step 2) x 94.0 / 100- Air Content (%) = 147.7 *

* This corrected cement meter count must be within ± 2% of the calculated cement meter count (step 1). OK