NACOE
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FINAL REPORT

NACOE P185: Calibration of Volumetric Concrete Mixer Trucks

NTRO Project No.: Prj-25-03815

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Prepared for:	Queensland Department of Transport and Main Roads	

DATE: 27 April 2026

Version: 1.0

AN INITIATIVE BY:

NTRO Queensland Government

Summary

The National Asset Centre of Excellence (NACOE) P185 report investigates the calibration of volumetric concrete mixer trucks, which differ from traditional batch plants by dispensing raw materials based on volume rather than mass. Volumetric mixers provide flexibility for remote projects, small volumes and specialised mixes, but face challenges because Australian Standards (AS 1379:2007 R2017) and Queensland's MRTS70 specifications are based on mass batching.

If broader consideration is to be given to the acceptance of volumetric concrete mixer trucks in Queensland Department of Transport and Main Roads (TMR) infrastructure projects, establishing the calibration procedures is an important step. This study assessed current calibration practices of volumetric concrete mixers operating in the Australian market and compared them with existing local and international standards to inform recommendations for calibration procedures.

A targeted literature review demonstrated significant precedence for the acceptance of volumetric concrete mixers, especially in North America based on American Society for Testing and Materials' (ASTM) standard and American Concrete Institute (ACI) guidelines. A review of the batching tolerances under these North American standards indicated no expected reduction in batching accuracy when compared to AS 1379:2007 R2017.

Consultations with multiple contractors that operate volumetric concrete mixers in Australia were undertaken during this project, which confirmed that the Australian Standard AS 1379:2007 R2017 mass-only requirement is unsuitable for mobile volumetric mixers.

Suppliers confirmed that calibration and production processes in Australia are substantially reflective of North American practices. Suppliers emphasised that through standardised calibration requirements including yield and proportioning checks, daily preproduction testing, and defined calibration intervals, it is possible to ensure compliance with the quality control requirements of Australian Standards AS 1379:2007 R2017 and most project specifications including MRTS70.

In addition, volumetric concrete mixer trucks meeting these calibration and control requirements, can discharge concrete into agitator trucks for further mixing and transport of the concrete to site, In this case the volumetric concrete mixer truck is effectively functioning as a mini mobile concrete batching plant. Based on the presumed acceptability of the broader use of volumetric concrete mixer, as detailed in this report, by specifying agencies, this report proposes specification clauses nominating recommended minimum controls for volumetric concrete mixer trucks, including for calibration requirements adapted from American Concrete Institute guidelines.

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1. Introduction

1.1 Background

Volumetric concrete mixer trucks are small capacity mobile batch plants that produce concrete based on the volume of raw materials released, rather than the traditional method of batching quantities by mass, prior to mixing. The raw materials may be loaded into bins on the volumetric concrete mixer trucks and transported to site. Once the mixer is set up, the concrete can be produced onsite in an auger system that continuously blends raw materials as they are dispensed through multiple gates. This presents several advantages over traditional methods, including, but not limited to, reduced time between concrete mixing and pouring, improved suitability for remote areas, and the capability to produce rapid-set and bespoke concrete mixes. An additional benefit includes the ability to produce concrete mixes as required, allowing one truck to produce several concrete mixes. This reduces both waste and transport costs. Alternatively, the volumetric concrete mixer truck can be configured as a stationary continuous mixer to batch larger volumes of concrete, if aggregates, cementitious materials and water are supplied continuously.

As the usage of volumetric concrete mixer trucks becomes more widely adopted, it is imperative that the procedure for the supply of concrete using these types of mixing trucks, and the associated quality management are established. Current standards that regulate the implementation of volumetric concrete mixer trucks in Queensland are Queensland Department of Transport and Main Roads (TMR) Specifications MRTS70 *Concrete* and Australian Standard AS 1379:2007 R2017 *Specification and Supply of Concrete*.

Section 4.1.2 of AS 1379:2007 R2017 requires the measurement of all raw materials by mass, excluding water and chemical admixtures, for the batching of concrete above the 28-day characteristic compressive strength of 15 MPa. For continuous mixing applications, cements and aggregates must be dispensed and weighed by mass. Dispensing continuously mixed concrete solid raw materials by other means such as monitoring belt speed or auger speeds without additional monitoring for mass is not acceptable under AS 1379:2007 R2017 Clause 4.3.1.1. MRTS70 allows for the usage of volumetric mixers up to a maximum batch size of 5 m^3, subject to approval. Typically, acceptance is considered to use volumetric mixers when:

1. Smaller volumes are required.
2. Supply is needed in areas remote from conventional concrete batch plants.
3. Specialist concrete mixes are required.

All concrete produced in volumetric concrete mixer trucks is required to conform with the requirements of MRTS70. Because AS 1379:2007 R2017 does not provide for continuous batching of concrete by volume, a gap currently exists in the specified requirements for calibration of volumetric mixer trucks.

Clause 10.4 of MRTS70 requires the calibration of volumetric mixer trucks to be every 3 months, but no guidance is given on the calibration requirements. To aid with the continued usage and implementation of volumetric concrete mixer trucks, standardisation and or documentation of calibration procedures is required.

1.2 Objectives

The objectives of this investigation were to:

- investigate current practice of the calibration of volumetric concrete mixers, including industry practices and established existing guidelines
- compare current practice with available guidance in MRTS70 and AS 1379
- recommend calibration practices.
- Investigate whether a volumetric mixer can load a concrete agitator truck to further mix and transport the concrete to site, and the resultant concrete comply with MRTS70 and AS 1379:2007 R2017.

1.3 Scope

The scope of this project included:

1. a targeted literature search on recommended practices for calibration of volumetric concrete mixers
2. industry engagement to establish current practices
3. comparison of recommended practice and current industry practice
4. recommendation of calibration requirements for use in Queensland.

2. Summary of Concrete Batch Plant Calibration and Uniformity Requirements in Queensland

To ensure the quality of concrete produced and used in Queensland, AS 1379:2007 R2017 and MRTS70 outline the requirements for its supply and quality, including the calibration of associated equipment.

2.1 Principles of Calibration

The intent of calibration for concrete production purposes is to ensure that all materials of the concrete mix design are correctly measured, dispensed, mixed and delivered to site. The production of concrete requires precise mixing of cement, aggregates, water and admixtures in specific quantities. Any deviation from the expected quantities can result in variations to the concrete mix. This may result in detrimental effects, including non-conformance and/or rejection of the supplied concrete. Calibration also applies to all equipment involved in concrete production and transport to ensure consistent, high-quality performance. This includes, but is not limited to, scales, timers, valves, gates, mixers and agitators.

2.1.1 Why Calibrate

All batching plant and measurement instrumentation used in the production of concrete are subject to error. Common factors that can result in the reduced accuracy and repeatability of the utilised equipment are:

- sustained usage resulting in damage or wear of critical components
- exposure to external environments such as moisture, temperature and vibrations
- physical damage during transportation or use
- electrical surges or interference
- software errors
- operational errors.

The above factors can result in equipment producing varied results from the actual measured or expected results. To ensure that all equipment continues to operate at acceptable tolerances, regular calibration is required. The requirement of the calibration procedures and timing should be as per the requirements of the batching plant and/or relevant specifications.

2.1.2 Types of Measurement/Control Devices

The established methods for measurement and control of materials in concrete are outlined below.

Gravimetric

Provided for in AS 1379:2007 R2017, gravimetric measurement relies on the use of weight to determine the quantity of the raw material in concrete. This is typically completed using scales or continuous feeders that allow for the continuous measurement of weight. Gravimetric measurements are calibrated using a known load at set intervals.

Volumetric

Volumetric measurement observes the volume of a given material for determination of the amount of the material. It is traditionally used for liquids with a set density, and calibration is done against a known volume to confirm accuracy. Volumetric measurement of materials requires materials to have an established consistent density.

Flow rate

Flow rate provides a standard volume/mass per unit of time and can be used to determine the amount of material added to a mix. Calibration is generally performed by measuring the amount of material produced under a standard pressure per unit of time and allocating a set flow rate.

Moisture probes

Monitoring aggregate moisture content is essential for concrete batching, as it provides a source of free water in the concrete mix. If adequate compensations are not made to the batch water, concrete may be produced with uncontrolled water content, which affects the expected slump, strength and shrinkage performance. Aggregate moisture monitoring is especially important for fine aggregates, as the capillaries in stockpiled sand have a high potential to retain excess water for a short time. Excess water is also likely to drain to a lower moisture content when undisturbed.

Moisture probes are one method for monitoring the real-time moisture content of fine aggregates, which then allows for compensation of the batch water content. Moisture probes estimate the moisture content of fine aggregates by measuring their electrical properties – either using electrical resistance or dielectric permittivity – and require regular calibration for the specific material. Moisture probes should be routinely calibrated against established laboratory tests including AS 1289.2.1.1:2005 (oven drying method), AS 1289.2.1.4:2005 (microwave oven drying method) or AS 1289.2.1.6:2005 (hotplate drying method).

Neither AS 1379:2007 R2017 nor MRTS70 prescribe the method of conducting aggregate moisture testing; however, AS 1289.2.1.1:2005, AS 1289.2.1.4:2005 and AS 1289.2.1.6:2005 are commonly adopted by Australian concrete suppliers.

2.1.3 When to Calibrate

To ensure the accuracy of production, calibration should be undertaken at several key events, namely:

- initial setup
- after any significant changes, including repair and maintenance
- at established regular intervals; this varies depending on the equipment, manufacturer's recommendation and specifications.

Calibration can also be undertaken at ad hoc intervals to ensure accuracy is being achieved at the request of the client or the supplier. It is standard for large projects to outline separate requirements for calibration of equipment in addition to the suppliers' existing requirements.

Due to material variability across different sources, such as aggregates varying between quarries, calibration is required when the raw materials are changed to ensure the equipment is accurately measuring all inputs.

2.2 Summary of Current Requirements for Concrete Batching Calibrations

2.2.1 Current Requirements of MRTS70 and AS 1379:2007 R2017

Batching plant calibration and frequencies

Clauses 3.3.2 and 3.4.2 of AS 1379:2007 R2017 mandate a minimum calibration frequency of 6 months for weighing and liquid dispensing equipment or 'at a frequency that accounts for the type of equipment and the quantity of the concrete produced in the period between calibrations.

Clause 3.5.1 of AS 1379:2007 R2017 includes general requirements for both batch mixers and continuous mixers. Mixers may be deemed to comply based on mixer uniformity tests conducted on the mixer or of an identical prototype mixer. This includes mix uniformity requirements (see section below) and inspection at intervals of 6 months or after 2,300 m^3 of production, ensuring adequate mechanical conditions with limited wear as detailed in this clause.

AS 1379:2007 R2017 requires that aggregate and cement materials are measured by mass for continuous batching of concrete. Therefore, continuous mixers that monitor weigh measurements (such as belt weighers or reverse-weigh hoppers) may be considered for compliance with AS 1379:2007 R2017, whereas mixers that monitor only feed rates (belt speed or auger rotations) are non-compliant with the standard. Clause 10.2 of MRTS70 requires a minimum calibration frequency of 6 months for weighing equipment. General requirements are presented for the calibration of liquids, but no minimum frequency is presented.

Clause 10.4 of MRTS70 requires the calibration of volumetric mixer trucks every 3 months. The specific calibration requirements are not defined and are assumed to follow manufacturers' recommendations.

Moisture compensation

Clause 4.1.3 of AS 1379:2007 R2017 dictates a requirement for the adjustment of the mix for free moisture on the surface of the aggregates but provides no guidance on the preferred method.

Clause 10.2 of MRTS70 dictates a requirement for the moisture content of fine aggregate to be determined daily but does not specify a preferred testing method.

Mixer uniformity and compliance of mixers

Clause 3.5 of AS 1379:2007 R2017 outlines mixer requirements as below:

- compliance with Appendix A of AS 1379:2007 R2017 *Uniformity of Mixing*
- inspection of equipment after 6 months or after 2,300m^3 of concrete production for
  - quality of parts
  - confirmation of revolutions per minute
- calibration of minimum mixing time for concrete mixes.

AS 1379:2007 R2017 Clause 3.5.3 notes that the charging rate of continuous mixers shall be adjusted so that the discharge capacity specified by the manufacturer of the mixers is not exceeded and mixer uniformity tests are passed. Identification plates shall confirm the maximum discharge rate in tonnes per hour.

To satisfy the mixer uniformity test, 2 samples must be taken from the produced plastic concrete. For continuous mixers, the 2 samples are collected after at least 2 m^3 of concrete has been discharged between them. Testing shall consist of:

- slump
- air content
- mass per unit volume of plastic concrete
- coarse aggregate content
- mass per unit volume of air-free mortar.

The samples need to satisfy the requirements of Table A1 of AS 1379:2007 R2017 to pass the uniformity of mix test. A continuous mixer is non-complying if the mixer is not capable of operating at more than half the rated mixing capacity (AS 1379:2007 R2018 Clause 3.5.1(b)(iii)). Clause 10.3 of MRTS70 endorses the requirements of AS 1379:2007 R2017.

Clause 3.3.2 of AS 1379:2007 R2017 requires weighing equipment to be accurate to ±0.4% of the maximum scale value, and Clause 3.4.2 requires equipment for the measurement of water to be accurate to ±2%; all other liquid measuring equipment are required to have an accuracy of ±5%.

Clause 3.3.4 of AS 1379:2007 R2017 further describes the requirements for continuous feed weighers, such that they minimise the effects of impact and vibration and prevent contact between materials being weighed and any fixed part of the mixer. Further tolerances are outlined for the measurement of materials for continuous production in Clause 4.3.1. The mass flow rate of cementitious material shall be within −1% to +5% of the required rate, and the mass flow rate of aggregates shall be within −4% to +2% of the required rate.

Clause 10.2 of MRTS70 requires the volumetric measurement of water to be calibrated to 1.0-liter increments, with measurements of admixtures to be whichever is higher of ±5% or 20 ml. No further guidance is provided for tolerances during batching.

2.2.2 International Methods for Calibrating Volumetric Concrete Mixers

Several documents from the USA have been identified that give precedence for the calibration and use of volumetric concrete mixers. In general, these were found to align with MRTS70, which mandates the general calibration of volumetric concrete mixers without specific requirements. The key documents identified include:

- American Society for Testing and Materials ASTM C 685:2017, *Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing*
- American Concrete Institute ACI 304.6R-09(19), *Guide for the Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment*
- New York State Department of Transportation Materials Bureau NYSDOT:1979, *Calibration of Mobile Mixers (Concrete-Mobiles) to Produce Portland Cement Concrete*
- Volumetric Mixer Manufacturers Bureau (VMMB) 100-01:2001, *Volumetric Mixer Standards of the Volumetric Mixer Manufacturers Bureau*.

Both the NYSDOT (1979) specification and VMMB 100-01:2001 reference ASTM C 685:20172017 for their recommended batching tolerances and calibration methods. ASTM C 685 allows for the measurement of all raw materials by volume to produce concrete within the tolerances, which have been included in Table 2.1. For comparison, the tolerances for conventional batch plants and continuous production mixers as per AS 1379:2007 R2018 have also been included in Table 2.1.

As per ASTM C 685:20172019 Clause 7.8, the tolerances are ‘based on a volume/mass relationship established by calibration of the measuring devices furnished as an integral part of the whole equipment’. Clause 7.4 gives guidance that calibrations should be in accordance with manufacturers’ recommendations, with a suggested calibration procedure given in ACI 304.6R and VMMB 100-01. Under this procedure, 2 checks are nominated:

1. a yield check (mass per unit volume) to confirm the expected production of plastic concrete
2. a proportioning check (washout test) whenever raw materials are changed.
   This test measures the mass of course and fine aggregates from a known volume of plastic concrete, by washing through a 4.75 mm sieve and 0.15 mm sieve, respectively. The aggregate is weighed and compared to the expected mass.

Clause 8 of ASTM C 685:20172017 requires continuous mixers to satisfy mix uniformity requirements, which is functionally similar to AS 1379:2007 R2017 with varying tolerances. Additionally, it stipulates the following:

> Each batching or mixing unit, or both, shall carry in a prominent place a metal plate or plates on which are plainly marked the gross volume of the unit in terms of mixed concrete, discharge speed, and the mass-calibrated constant of the machine in terms of a revolution counter or other output indicator.

Clause 14.1.2 requires the calibration and mixer efficiency testing to be completed ‘at intervals not exceeding 6 months’.

ACI 304.6R-09(19) outlines practical recommendations for the use of volumetric concrete equipment, including a comprehensive calibration procedure. Calibration is required for each raw material feed. The recommended methodology for calibration is to validate the actual volume produced against the expected

volume by confirming the corresponding weight. This is achieved through a straightforward measurement exercise using a calibrated scale, a stopwatch and a container. Before starting, the mixer should be prepared by removing all raw materials except the one being calibrated, which is then discharged into the container for measurement.

For cement, it is recommended that a minimum of 5 tests are conducted for measuring the minimum time run for producing at least 94 lb (approximately 43.5 kg) of cement. Once discharged, the raw material is weighed, and the process is repeated at least 5 times to develop a volume/mass flow rate for use in concrete design.

Aggregate discharge needs to be calibrated in relation to the cement discharge rate to ensure accuracy for a given mix design. The ACI committee report (ACI 1997) suggests that aggregate calibration can include a graph of volume/mass flow rate for 5 different control (gate height) settings. This relationship is non-linear and will require separate calibration for different flow rates of materials.

To confirm that the calibration has been successfully completed, it is recommended that a volumetric yield test (mass per unit volume) is completed along with standard preproduction tests. A yield test is a comparison of the expected volume of plastic concrete against the actual volume of plastic concrete produced, and it confirms whether or not equipment has been calibrated correctly. Preproduction tests are the standard concrete tests such as air content, slump and unit weight. It is recommended as best practice to perform these tests once a day or after 50 yd^3 (38 m^3) of production to confirm calibration.

Notwithstanding the above calibration requirements, general requirements are given regarding the produced concrete mix, such as uniformity, slump, air content and strength.

The NYSDOT outlines a calibration procedure that aligns with the procedure recommended by ACI 304.6R but includes pre-calibration checks for inspection of:

- cement bins
- ground straps to ensure grounding of unit to prevent static electricity and cement clinging to bins
- cement meter-feeders
- all belts
- vibrators
- tachometers to ensure consistent operational speed of units.

The key differences in the calibration procedure include volume of raw materials dispensed, number of trials and specific system requirements.

The VMMB standard reoutlines the requirements of ASTM C 685:2017 in more general terms and does not provide any specific guidance on calibration requirements.

NYSDT (1979) and ACI 304.6R-09(19) recommend calibration for volumetric concrete trucks to be undertaken:

- at initial calibration
- after significant repair or maintenance
- at 6-month intervals
- at the request of the [Principal's] engineer
- if concrete raw materials have changed or sources have changed
- if it is believed that the materials have varied since calibration, possible causes include
  - compaction during transport
  - exposure to moisture.

NYSDT (1979) allows for calibration whenever the unit departs from or returns to the job site, noting the option for a partial calibration, although this is not defined.

Manufactures' guidelines

Several mixer truck manufacturers' websites were reviewed to investigate recommended calibration procedures. Manufacturers reviewed included:

- PROALL, Training Videos (https://proallinc.com/resources/training-calibration-videos/)
- Cementech, Training Videos, (https://cementech.com/service-support/service-plus/)
- Bay Lynx, General guidance, (https://bay-lynx.com/calibration-what-is-the-procedure-and-why-is-it-important/).

A high-level review of calibration procedures recommended by the above manufacturers was undertaken. The procedures generally align with the intent of ACI 304.6R-09(19), requiring calibration to be performed by validating flow rates against weight for each specific raw material. Several equipment manufacturers have inbuilt systems for the calibration procedure, allowing for the system to automatically update its mix designs for volumes dispensed and to guide the calibration procedure. Guidance for the frequency of calibration ranged between annual to semi-annual and whenever new materials were introduced.

2.2.3 Summary of Requirements

A summary of the required tolerances as per ASTM C 685 and AS 1379:2007 R2017 are presented in Table 2.1 for comparison. To provide an indication of the AS 1379:2007 R2017 tolerances as a percentage, the tolerances have been represented as a proportion of a nominal S40 grade concrete mix design, with typical load size of 6.0 m^3.

Table 2.1: Concrete raw material tolerances of ASTM C 685:2017 and AS 1379:2007 R2017

Parameter	ASTM C 685:2017 allowable tolerance	AS 1379:2007 R2017 allowable tolerance for continuous production	AS 1379:2007 R2017 allowable tolerance for weigh-batching, > 4 m^3	AS 1379:2007 R2017 calculated tolerance for weigh-batching a typical S40 mix (4.0 m^3) (1)
Cement	0% +4% by mass	−1% +5% by mass	−20 +40 kg	−1.3% +2.5%
Fine aggregate	±2% by mass	−4% +2% by mass	±100 kg	−2.2% +2.2%
Coarse aggregate	±2% by mass	−4% +2% by mass	±100 kg	−3.3% +3.3%
Admixtures	±3% by mass or volume	±5% by mass or volume	±5%	–
Water	±1% by mass or volume	See note 1	See note 2	See note 2

1. Typical concrete proportions assumed (per m^3 of concrete) include 400 kg General Purpose Blended (GB) cement, 1,130 kg coarse aggregate, 760 kg fine aggregate.
2. AS 1379:2007 R2017 Clause 4.2.1.2 permits water tolerance to be controlled either by slump testing or by managing the water-cement ratio through mix design.

From the tolerances outlined above, volumetric batching tolerances from ASTM C 685 are typically stricter than AS 1379:2007 R2017 continuous production batching requirements. Similarly, the allowable tolerances under ASTM C 685:2017 for aggregates are conservative (more stringent) when compared to an equivalent proportional tolerance of AS 1379:2007 R2017 for 4.0 m^3 of a typical S40 concrete mix.

Compared to ASTM C 685:2017 tolerances, AS 1379:2007 R2017 (for conventional weigh-batched concrete) has a similar range of tolerance when compared to a typical S40 concrete mix; however, ASTM C 685 does not allow batching below 0%, which is, therefore, considered more conservative.

2.2.4 Gaps Within Current Standards

AS 1379:2007 R2017 does not allow for the continuous production of concrete using volumetric measurements alone, where the mass of raw materials is not metered. MRTS70, additionally, restricts the use of volumetric mixer concrete trucks to a batching volume limit of 5 m^3. Current Australian Standards restrict the use and application of volumetric concrete mixer trucks through limiting where the current technology can be applied.

Volumetric concrete mixer trucks use a continuous mix with volumetric measurements. Currently, AS 1379:2007 R2017 allows for the use of continuous mixing under Clause 4.3, provided the mixer production is under the rated capacity and the uniformity testing stipulated in Appendix A is satisfied. This indicates that the issue prevalent is with the measurement of the raw material and the variability resulting from volumetric measurements of materials. This aligns with guidance given in ACI 304.6R-09(19), which notes that an experienced operator is required. It also suggests that aggregates can become compacted in bins during transport, and the draining of water to lower levels can cause errors in flow rate.

The key gaps identified are around the calibration and usage of the equipment. Established procedures exist to confirm the quality and suitability of the concrete produced, but a gap exists on the measurement and mixing of the raw material. Without established guidelines to confirm the accuracy of the measurements of the raw material used in volumetric concrete mixer trucks, the reliability and confidence in the concrete produced is reduced. This results in individual manufacturers outlining different calibration requirements for the usage and production of concrete, subsequently leading to variability and inconsistency across industry.

Volumetric concrete mixer trucks require a standardised method of calibration to confirm the accuracy of the measurements for the raw materials for concrete mix designs. An establishment of the procedures to be undertaken by the operator to enable the use and gain confidence in the product produced is required.

Based on the comparisons discussed in Section 2.2.3, the batching tolerances of an appropriately calibrated volumetric mixing truck in accordance with ASTM C 685:2017 would be expected to meet the batching tolerance requirements of those under AS 1379:2007 R2018, noting only the permissibility of a slight increase in the total cementitious material content acceptable with the ASTM C 685:2017 based volumetric mixer.

2.2.5 Preliminary Considerations for MRTS70

Considerations to improve the calibration requirements of MRTS70 (for both conventional and volumetric concrete mixers) may include:

- a requirement for aggregate moisture content testing daily or for each load of fresh material received
  - aggregate moisture content testing method to be defined as AS 1289.2.1.1, AS 1289.2.1.4 or AS 1289.2.1.6
- discretionary ability of the Principal to direct a mixer uniformity be conducted, upon reasonable suspicion of poor mixing efficacy
- defining the calibration frequency for water and admixture measuring devices.

Proposed specification clauses relating to acceptance of volumetric concrete mixers based on the ASTM C 685 standard have been included in Section 4.1.

3. Volumetric Concrete Mixer Truck Calibrations

Several companies who specialise in the operation of volumetric concrete mixer trucks were contacted to provide an overview of their existing batching and calibration methods. Due to the commercial nature of the operations discussed, the information below has been generalised and is considered reflective of current industry practice.

3.1 Description of Volumetric Concrete Truck Mixers

3.1.1 Mixing Plant Description

The majority of volumetric concrete mixer trucks are sourced from or developed for North America, which has an established industry in volumetric concrete production. Typical mixer configurations discussed had the following characteristics:

- dual aggregate bins, for fine and coarse aggregate
- onboard water tank
- single cementitious material bin
- multiple admixture tanks
- onboard computer
- either manual or electronic controls for batching proportions, in accordance with an established calibration.

Mixers can be mounted on rigid trucks or as semi-trailers. Aggregate materials are dispensed via gates onto a central belt. Liquids are dispensed by flow meters and cement is dispensed via a screw auger. The largest variability of the mixers was noted to be the onboard computer, with some mixers using manual controls. The functionality of both manually controlled or electronically controlled plant is the same.

The effect of the onboard computer has been summarised in Table 3.1, noting that the software and degree of automation varies between mixers. For a given mix design, the mixer settings will be fixed to ensure a consistent mix is produced, and only minor adjustments in water are made to account for minor changes in aggregate moisture and to target consistent slump. Modern mixers allows the onboard computer to adjust settings, according to the calibration inputs and mix design.

Table 3.1: Categories of volumetric concrete mixer trucks

Manually operated	Computer assisted	Computer operated (emerging)
• Gate heights to be set by operator • Control sheets for mixer set up, batching and mix designs held locally • No variation while operated • Manual calibration	• Gate heights set by computer • Mix designs stored on computer • Minor variation to gate heights under operation • Computer calibration • Mixing plant will record all inputs and production output	• Gate heights set by computer • Mix designs stored on computer • Adjustments to all elements allowed by computer during operation • Computer calibration • Mixing plant will record all inputs and production output

From industry engagement, the most common mixing plant currently used in Australia is the computer-assisted volumetric concrete mixer truck.

The mixer can be operated in 2 modes: as a mobile mixer or a stationary mixer. As a mobile mixer, the standalone trucks have a capacity of approximate 5–7 cubic metres of concrete, while the semi-trailers have a capacity of approximately 8–9 cubic metres of concrete, noting that the capacity is limited by legal road weight limits. As a stationary mixer, the production is limited by the production rate and the capacity to load the mixer. This requires aggregate to be fed from stockpiles, water from an external supply (normally a water

cart) and cement from an external supply (ISO container, tanker or from 1,000 kg bulk/bulka bags). This production method has been successfully implemented on multiple projects. As a stationary mixer, the concrete can be discharged into concrete pumps or concrete agitators if an acceptable working platform is built to manage the difference in heights.

3.1.2 Mixing Plant Configuration and Processes

Mixing plant establishment

Volumetric mixers can be set up as a mobile mixer or as a stationary mixer for the production of greater volumes of concrete than its onboard capacity.

For projects using mobile mixing, mixers can be preloaded with known materials and operated based on a previously established calibration (typically completed within the past few months). This approach enables rapid setup, efficient production and quick site demobilisation.

Mixing plant calibrations

Calibration procedures are required for every combination of aggregate source and cementitious material types/sources. For example, changing the supplying quarry for coarse aggregates or sands, or changing from General Purpose Blended (GB) cement to a General Purpose (GP) cement, would all require a new calibration. The procedures for all companies interviewed followed the same general principles and are typically aligned with ASTM C 685 principles, described below. The calibration of water and admixture flow meters is typical to those undertaken in conventional premix batch plants.

Calibrations involve measuring the mass vs flow relationship for both cement and aggregates. The rate of aggregate flow can be changed by adjusting the gate height, which allows the proportion of aggregates to cementitious materials to be targeted for a given mix design.

Cement calibration involves dispensing 60–100 kg of material into a container of known volume over a set time to verify the weight. This process should be repeated at least 5 times for accuracy, though in field conditions it may be reduced to 3 repetitions.

Aggregates are calibrated on gate heights with the same methodology. For a given gate height, a set time is run dispensing between 60 to 100 kg of material. Similarly, this is to be repeated a minimum of 5 times but may be reduced to 3 due to field constraints. This is to be performed for all gate heights to develop a calibration curve for use in mix design.

Calibration would be repeated if any discrepancies were noted in the concrete or after approximately 2 months of usage. Changes in aggregate sources, aggregate properties or cement types would also trigger a complete recalibration.

Mixing plant controls

Mix designs are developed based on calibration curves for materials, which are developed using the process above; these show the flow rate of the aggregates. Using the calibration curves, the mix designs are developed based on the flow rates and gate heights of aggregate for a given belt speed. This belt speed is directly linked to the screw auger of the cement bin for manual and computer-assisted mixers.

Water flow rate and admixture flow rates are also adjusted to match the discharge rate of the cementitious material.

Data is recorded by the onboard computer for computer-assisted mixers. This information includes gate height, belt speeds (or counts) and auger settings, which were used to determine calibrated flow rates and production volumes.

Daily operations and aggregate moisture

Prestart checks are dependent on project requirements and operational procedures.

Aggregate moisture tests are commonly undertaken daily with the batch water content adjusted accordingly. If changes in moisture content are significant, a new calibration of aggregate flow rate is typically required.

Minor changes in moisture content are not considered to have a significant impact on the batching accuracy of fine aggregates, where the flow characteristics are unchanged. Some aggregate materials, such as manufactured sands or sands with high clay and silt contents, may be more susceptible to changes in flow rate when compared to clean natural sands.

To mitigate variation in aggregate moisture content, many companies apply heightened controls in raw material handling, including covering aggregates (under tarpaulins) and conducting daily turnover of stockpiles to ensure a homogenous material.

Onsite controls varied between companies, with some preferring operators to adjust the water within defined limits, triggering an escalation process if the mix design deviates from standard operation. On the other hand, other companies preferred limited input from operators, with a preference towards the onboard computer managing the mix design.

Yield tests are a common control used to verify the expected accuracy of batching in-field.

Quality assurance

Quality assurance is performed by the companies, although this varies depending on internal operations and the project specification. Common quality assurance included slump testing, yield tests, washout tests, density tests and taking cores for visual inspection of aggregate matrix.

Mix uniformity testing is done by some companies to ensure compliance with AS 1379, although this is not a universal practice in the industry.

Feedback from multiple volumetric contractors indicated that (compressive strength) standard deviations are typically comparable (or better) than typical standard deviations from a conventional dry-batch premix concrete plant, indicating a high degree of confidence in repeatability.

3.2 Variances from TMR and Australian Standards Requirements

MRTS70 currently requires the calibration of continuous concrete mixers every 3 months, due to the calibration being unique to material types. However, it is currently unclear if this requirement is being met. Calibration of flow metres are in accordance with AS 1379:2007 R2017 and anticipated to be conducted every 6 months, as a conventional concrete plant requirement.

Currently, there is no provision within AS 1379:2007 R2017 for the use of volumetric mixers that are not weigh-metered, which includes all mixing plant principally developed to supply concrete to ASTM C 685. Therefore, there is no relative local specification for the calibration of volumetric concrete mixers that are built on US standards.

The key gaps noted from Section 2.2.2 include:

- no procedure nominated for calibration of mixing plant
- no mixer uniformity requirements, noting ASTM C 685 mandates this every 6 months
- consistency for quality assurance testing
- consistency for prestart checks.

All gaps noted are covered in Section 2.2.2 and are currently implemented in the US market.

4. Considerations for Standards and Specification Updates

The key consideration with volumetric concrete mixer trucks is the accurate measurement of the raw material. The intent of minimum calibration is to provide a level of assurance that the produced concrete is within the tolerances outlined in AS 1379:2007 R2017. As discussed in Section 2.2, the batching tolerances acceptable for volumetric concrete mixers in accordance with ASTM C 685:2017 are more stringent than allowable conventional concrete mixing plant or continuous mixers under AS 1379:2007 R2017, representing no anticipated reduction in concrete performance. Only a slight increase in acceptable cementitious material content is noted under ASTM C 685:2017.

The suggested mixing plant calibration and batching inclusions in Section 4.1 presume that the specifying agency accepts the use of non-weigh metered volumetric batch plants for concrete production. This appears to be supported anecdotally from suppliers that concrete performance can be maintained to a high degree of quality and consistency.

4.1 Suggested Requirements

The information below is presented for consideration within MRTS70 or similar specifications governing the supply of concrete materials into transport-related infrastructure.

Use of volumetric concrete mixer trucks

Volumetric concrete mixer trucks, which are not equipped with weigh-meters for aggregates or cements, may be used in accordance with the following requirements.

[Optional clause] The use of volumetric concrete mixer trucks is not permitted for supply of concrete in high-risk concrete applications, including precast concrete members. The use of volumetric concrete mixers for structural elements is subject to the approval of the administrator and based on the contractor's ability to demonstrate a consistent quality of concrete production.

Mixing plant requirements

Volumetric concrete mixers shall:

- have separate partitions for coarse and fine aggregate
- have a minimum rated capacity of no less than 4 m^3
- have demonstrated compliance with the mixer uniformity requirements of AS 1379.

Mixer calibration

Calibration of aggregate and cement flow rates shall be conducted for each unique combination of coarse aggregate, fine aggregate and cementitious material. Calibration intervals shall not exceed 2 months for aggregates and cementitious materials.

Calibration of volumetric concrete mixer trucks shall follow the principles of ACI 304.6R-09(19) Appendix A, with the following metric system adaptations:

- Weigh scales shall have a minimum capacity of 150 kg and accuracy of ±0.4%.
- The sampling container shall have sufficient volume to contain 100 kg of aggregate or cement material.
- The moisture content shall be checked in accordance with AS 1289.2.1.1, AS 1289.2.1.4 or AS 1289.2.1.6.
- When dispensing material at operating speed to complete a calibration measurement, a minimum quality of 50 kg of material shall be dispensed.

To validate the calibration with a yield test, the mixer is to be run to produce 0.25 m^3 of concrete and dispensed into a container with a volume of 0.25 m^3.

Measurements of aggregate flow rates shall be conducted at a minimum of 5 gate height settings for each aggregate bin. Interim checks of less than 3 gate height settings may be conducted at any time within each 2-month calibration period.

Records shall be kept stating the material, gate height, amount and time dispensed, and calibration curve produced to be made available for viewing at an audit.

The use of gate settings that fall outside of the range covered by the calibration shall not be permitted.

Water and admixture calibrations shall meet the requirements of AS 1379:2007 R2017 and be conducted at intervals not exceeding 6 months.

All mixers shall be conformant with mix uniformity testing outlined in Appendix A of AS 1379:2007 R2017. Regular inspections shall be performed on the mixing blades to confirm no hardening of concrete or wear on the blades is observed. If observed, mix of uniformity testing may be required.

Aggregate moisture control

Fine aggregate moisture tests are to be conducted daily and mixer water settings adjusted to compensate for aggregate-free water.

If the moisture content of fine aggregates at the time of batching falls outside of ±2% of the moisture content at time of calibration, an interim check of the aggregate flow rate at the intended gate setting shall be undertaken using the same calibration procedure. If the aggregate flow rate falls within 2% of the flow rate at last calibration, when adjusted to equivalent moisture content, the aggregate moisture content shall be accepted.

If the aggregate flow rate exceeds 2%, a complete recalibration of aggregates must be undertaken.

Aggregate stockpiles shall be covered to protect from significant changes in moisture content. Aggregate stockpiles shall be turned over and homogenised daily prior to loading concrete mixer trucks.

Use of a volumetric mixer truck as a stationary mixer

The use of volumetric concrete mixers that meet the above requirements may be used as a stationary mixer to increase the potential production volume.

The discharge of concrete into conventional agitator trucks for site delivery is permitted, conditional on the concrete agitators meeting the mixer uniformity requirements of AS 1379. Where conventional concrete agitators are used, the volumetric concrete mixer truck is not required to demonstrate compliance with mixer uniformity requirements. Concrete dispensed into a concrete agitator will comply with the requirements outlined in MRTS70.

5. Conclusion

The literature reviewed showed that ASTM C685:2017 Standard and ACI 304.6R-09(19) guideline for volumetric concrete mixer trucks are prevalent internationally. A core difference between ACI and Australian Standards is the requirement for weigh-metering of aggregates and cements (under AS 1379).

Most of the volumetric concrete mixer trucks used in Australia, as indicated by several supplying contractors, are developed for the North American concrete market, and therefore, the calibration and operational procedures align more closely with ASTM C 685 and ACI 304.6R-09(19).

The key requirements for the calibration of volumetric mixers to the ASTM C685 method include:

- developing calibration curves (volume flow rates vs mass) for all unique solid materials through dispensing materials and manual weighing
- developing mix designs based off calibration curves
- volumetric yield testing to confirm calibration and mix design
- mix of uniformity testing.

Additionally, consultations with several concrete suppliers have shown that the following checks are often undertaken:

- increased controls of aggregate stockpiles for moisture, including tarping and daily blending
- daily moisture checks to confirm material is the same as the calibrated material
- prestart spot checks to confirm calibration
- increased quality assurance activities, including coring to confirm aggregate matrix, slump testing, air content and density tests.

With the presumption that TMR or other agencies may consider updating their specifications to facilitate the use of volumetric concrete mixer trucks that are typically aligned with North American market requirements, proposed specification clauses have been drafted for adaptation. These include calibration procedures, mixer uniformity requirements, aggregate handling practices (particularly regarding moisture control) and additional quality control tests.

In addition, volumetric concrete mixer trucks meeting these calibration requirements, can discharge concrete into agitator trucks for further mixing and transport of the concrete to site. In this case, the volumetric concrete mixer truck is effectively functioning as a mini mobile concrete batching plant.

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