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CCMPA SPECIAL TECHNICAL BULLETIN

SPECIFIED COMPRESSIVE STRENGTH OF CMU

To Our Producer Members

Over the past few months, a number of problematic field issues have emerged pertaining to CMU block compressive strengths, required CMU markings, and compressive strength testing and compliance.

Because of the oftentimes very unfavourable consequences of supplying under-strength, non-compliant product, affecting the designer, contractor, and producer, and *the concrete block industry as a whole*, the CCMPA Engineering Department has issued this Bulletin to highlight and discuss the requirements in the CSA masonry standards pertaining to:

- required compressive strengths for CMU ;
- required compressive strength markings for CMU; and,
- required compressive strength testing and test frequency for CMU.

This Bulletin serves as a gentle reminder for our CMU member producers who are knowledgeable about these requirements, and implement suitable quality control procedures to ensure compliance.

Perhaps more so, this Bulletin is intended to be delivered as a “blunt force instrument” to those CMU producers who are ignorant of these requirements, who do not understand them, who disregard them, or who do not have suitable quality control procedures to ensure compliance. These producers risk damaging the credibility of our good industry, destroying the confidence of designers who seek to serve us and others, and harming relationships with our contractor partners and customers. *Ignorance of standard requirements and poor practices are wholly unacceptable; indeed, they are indefensible and inexcusable.*

1. Specified Compressive Strength of CMU

The *Specified Compressive Strength* of a concrete block masonry unit is defined and described in CSA Standard A165.1-04. Therein, four strength categories are identified in Table 1, under its second facet:

Table 1
Physical properties

Second	Minimum specified compressive strength calculated on average net cross-sectional area of the unit, MPa†
10	10
15	15
20	20
30	30

The *Specified Compressive Strength* is calculated based on the average net cross-sectional area of the unit, and is the attained 28-d compressive strength.

The *Specified Compressive Strength* is that block strength used in structural design and specified by the structural engineer for a particular construction project. Canadian designers most often choose 15 MPa, however, A165.1-04 also allows the designer to choose higher strength units. The strength of the masonry is directly related to the strength of the block units of which it is constructed. In fact, assuming reasonable construction practice, block strength affects masonry strength more than any other variable or consideration.

The structural engineer will only specify higher strength units where the masonry wall or column to be constructed must have higher strength in order to effectively resist the imposed loads. Delivery and use of units that satisfy the required/specified strength is critical to the safety of the design.

2. Required Specified Compressive Strength at Time of Shipment

Clause 5.1 of CSA A165.1-04 requires that the *Specified Compressive Strength* of the concrete block units be met at the time of shipment by the manufacturer to the job site:

5.1 Physical properties

The physical properties of concrete block masonry units at the point of manufacture and at the time of shipment by the manufacturer to the customer shall be classified in accordance with [Clause 3.1](#) and shall conform to the requirements of [Table 1](#).

There must be no substitution for units requiring a higher Specified Compressive Strength with units having a lower compressive strength.

Units that are shipped to the job site before the age of 28-days must achieve the required 28-d *Specified Compressive Strength* at the time of shipment. **Therefore, a concrete block unit sampled from a job site and tested for compressive strength must achieve the required compressive strength regardless of the age of the unit; because the unit is on-site, it must therefore have the required strength. If it does not, the unit is non-compliant, and unacceptable.**

Any idea that it is permissible to allow CMU to cure on-site and subsequently gain strength with time in order to achieve the required *Specified Compressive Strength* at 28-days, whether the units are included in the construction or simply stored on-site, is FALSE.

3. Visually Identifying the Specified Compressive Strength of a CMU

A structural design of a masonry wall or column is *always* based on a minimum compressive strength for the masonry, and therefore, on a required *Specified Compressive Strength* of the masonry unit. For what we might call “higher strength masonry” constructed of units having a *Specified Compressive Strength* higher than 15 MPa, the structural engineer requires assurances that, indeed, the masonry element has been constructed with the needed/specified high strength units. There is structural advantage to using higher strength units. **Masonry walls and columns designed for higher strength units, but constructed with lower strength units, may fail structurally, in service.**

Without some unique identification on its body, the strength of a unit cannot be determined by simple visual inspection because a 15 MPa will likely look no different than a 30 MPa unit. Other than by test, once units are distributed on-site from pallets by the mason, there is no means to verify the compressive strength of a unit without suitably identifying each individual unit.

Therefore, as a measure to ensure on-site quality, Clause 11 of CSA A165.1-04 requires that concrete block masonry units having a *Specified Compressive Strength* greater than 15 MPa be individually marked on their surfaces.

11 Marking

Concrete block masonry units having a specified compressive strength greater than 15 MPa shall be individually identified on one or more surfaces of the unit by the manufacturer.

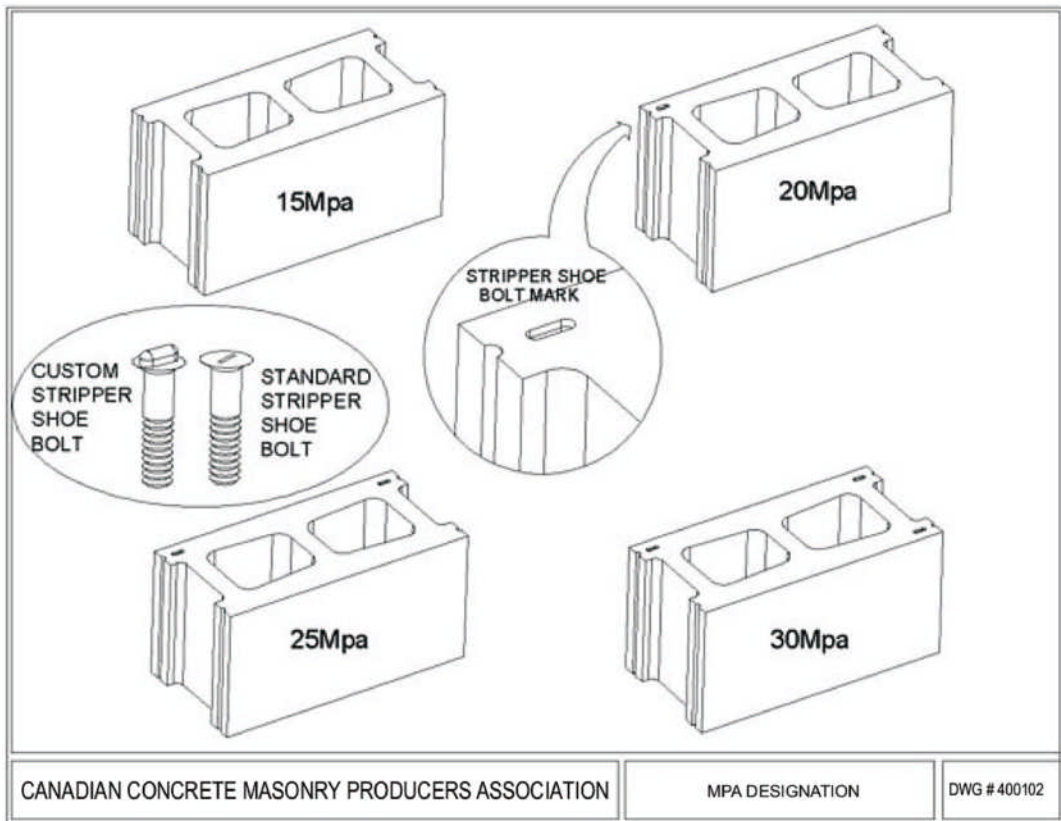
15 MPa units need not have an identification mark. By virtue of the absence of a mark, it is understood that the unit is intended to have, and is verified by test to have, a 15 MPa *Specified Compressive Strength*.

Units having a *Specified Compressive Strength* of 20 MPa and higher must be individually marked in order to suitably identify their strength. It is not sufficient to simply mark or tag pallets.

CSA A165.1-04 does not contain the standardized, industry-agreed-upon marking system. However, it is most likely that this standardized identification system will be placed in the next edition of CSA A165.1 (2014).

The standardized identification system, agreed upon by CCMPA membership some time ago, has been circulated to the CCMPA membership at various times shortly before and after the requirement for marking units was introduced into the 2004 edition of the A165.1 standard. A producer member that produces higher strength units intended to be used in the construction of higher strength masonry and marketed as such, and which has not introduced this marking system in their product, assuredly will be viewed by specifiers and designers as “dysfunctional”, likely among other descriptors.

The standardized identification system is illustrated below. This marking system also introduces a 25 MPa *Specified Compressive Strength* unit, not specifically recognized by a symbol under the second facet of Table 1 in A165.1-04.



Most assuredly, the structural designer is not ignorant to the requirements for CMU marking in material standard CSA A165.1. A cross-reference is contained in a note to Clause 15.1.2 of CSA S304.1-04, "Design of Masonry Structures". CSA S304.1-04 is used by the structural engineer for the structural design of masonry:

Note: CSA A165.1 requires manufacturers to identify all concrete block masonry units having a specified strength greater than 15 MPa. This reduces the likelihood of inadvertently constructing masonry with units having a compressive strength lower than specified.

4. Determining the Specified Compressive Strength of CMUs (at the Plant)

The requirements for sampling and testing to establish the *Specified Compressive Strength* of concrete block masonry units at the producer plant are stated in Clauses 10.1 and 10.2 of CSA A165.1-04.

The Specified Compressive Strength of concrete block masonry units is established by test, by the manufacturer, by engaging the services of a qualified, independent testing laboratory. The results of such testing is understood as the Specified Compressive Strength of the units "at the plant", or, "at the time of shipment".

As noted previously, the *Specified Compressive Strength* is calculated based on the average net cross-sectional area of the unit, and is standardized as the attained 28-d compressive strength. Average net cross-sectional area of a unit is determined in accordance with ASTM C140-03, "Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units".

Clauses 10.1 and 10.2 are excerpted from CSA A165.1-04:

10 Specified compressive strength

10.1

The compressive strength of concrete block masonry units shall be based on average net cross-sectional area.

Note: For compressive strength related to empirical design, see [Clause A.5.2](#).

10.2

The specified compressive strength of concrete block masonry units shall be based on a minimum of five test specimens and shall be calculated using

$$f'_{bl} = f_{av}(1 - 1.64v) = f_{av} - 1.64s$$

where

f'_{bl} = specified compressive strength, MPa

f_{av} = mean compressive strength of the test results, MPa

v = coefficient of variation = s/f_{av}

$$s = \text{standard deviation} = \sqrt{\frac{\sum(x - x_m)^2}{n - 1}}$$

where

x = an individual test result

$x_m = f_{av}$ = mean (average) of individual test results

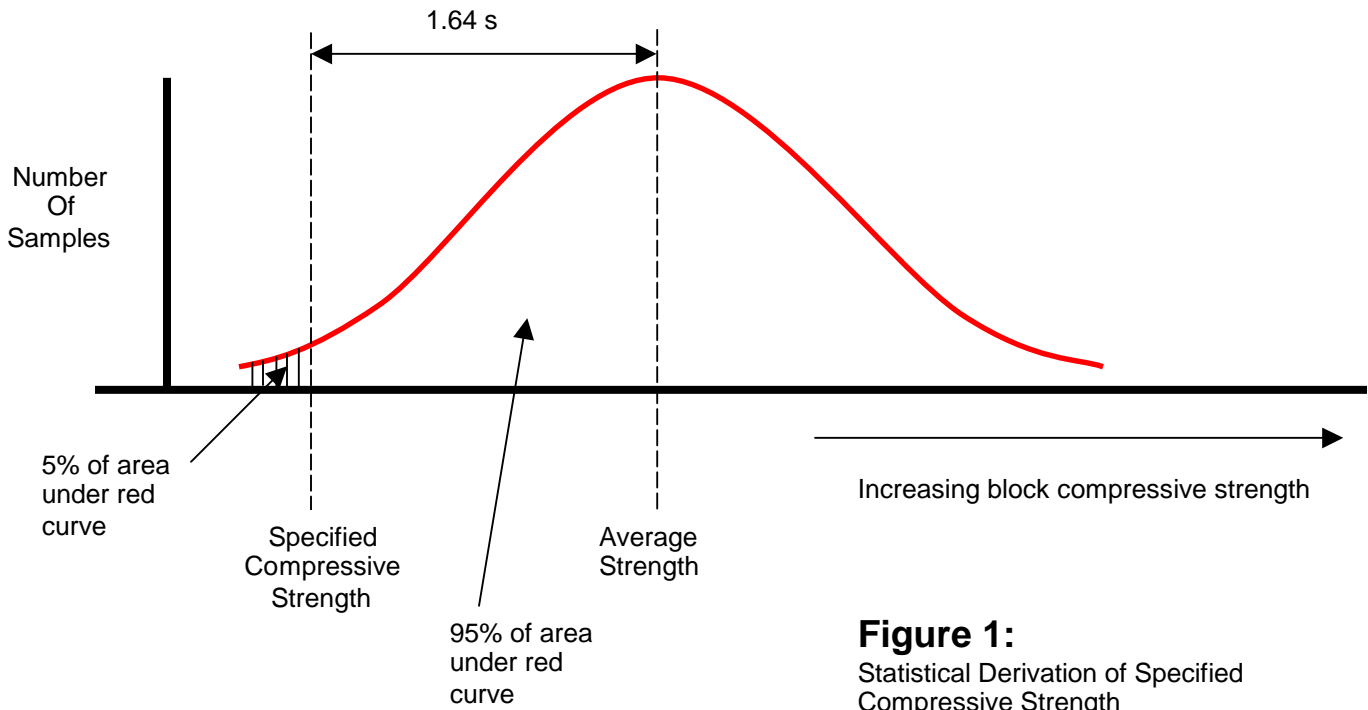
n = number of masonry units tested

If less than ten units are tested, the coefficient of variation shall be the greater of the calculated value or 10%. If the calculated value exceeds 15%, a minimum of ten units shall be tested.

Notes:

- (1) *The overall objective is to obtain a compressive strength for the masonry unit that will exceed the specified strength 95% of the time.*
- (2) *CSA S304.1 provides requirements for on-site verification of the specified strength of concrete block masonry units. CSA S304.1 requires that not less than five units be tested for compressive strength, that the average strength for these samples be greater than the specified strength, and that no individual test result be less than 85% of the specified strength.*

As described by the above clauses, the compressive strength test consists of either 5 or 10 samples. The calculation to determine the *Specified Compressive Strength* by the quality assurance staff of the producer and of the producer's testing agency/laboratory involves the statistical reduction (by 1.64 x standard deviation) from the average strength of the samples. The factor, 1.64, statistically reduces the reported strength, with the overall objective to obtain a compressive strength for the masonry unit that will exceed the *Specified Compressive Strength* 95% of the time. This statistical reduction uses the Normal Distribution Curve, and is graphically illustrated in Figure 1, next page.



5. On-site Verification of the Specified Compressive Strength of CMUs

Requirements to verify compressive strength compliance during course of construction are stated in Clause 15 of CSA S304.1, "Structural Design of Masonry".

Whereas the *Specified Compressive Strength* of the CMU is determined by sampling, testing, and calculation "at the plant" by the manufacturer using the requirements in CSA A165.1-04, compressive strength verification of units on a project during course of construction is undertaken by an independent testing agency whose services have been engaged either by the Owner or by the contractor. Test samples are selected from units that have been delivered to the job site.

The relevant excerpts from S304.1-04 pertaining to course of construction testing are provided on page 7, herein.

Simply stated, a test to verify *Specified Compressive Strength*, undertaken periodically during course of construction, consists of sampling five (5) units from the job site, testing for compression in accordance with ASTM C140-03, and averaging the recorded strength of the five (5) units. The average compressive strength must exceed the *Specified Compressive Strength* required by the project specifications, and no individual test strength result can be less than 85% of this *Specified Compressive Strength*.

15 Field control tests during construction

15.1 Masonry unit tests

15.1.1 Test frequency

At least five masonry units shall be selected and tested in conformance with [Clause 5.1.3.4](#)

- (a) for each 500 m² of wall or portion thereof for each unit type and for each storey; and
- (b) for each 250 m² of wall or portion thereof and for each storey for concrete masonry units with specified strength higher than 15 MPa, and for clay masonry units with specified strengths greater than 25 MPa.

15.1.2 Design strength based on masonry unit and mortar tests

Where the specified compressive strength used for design is based on unit, mortar, and grout tests in accordance with [Clause 5.1.3](#), the average of any compressive test referred to in [Clause 15.1.1](#) shall not be lower than the specified compressive strength of the units used in the selection of f'_m as provided in [Clause 5.1.3.5.1](#) or [5.1.3.5.2](#), and no individual test result shall be less than 0.85 of the specified strength.

Where the specified compressive strength of the masonry unit used for design is not greater than 15 MPa, field control testing for compressive strength of the masonry units may be waived if the producer of the masonry units provides test data to demonstrate that the strength of the units is not less than the specified compressive strength.

Note: *CSA A165.1 requires manufacturers to identify all concrete block masonry units having a specified strength greater than 15 MPa. This reduces the likelihood of inadvertently constructing masonry with units having a compressive strength lower than specified.*

15.1.3 Design strength based on masonry prism tests

Where the specified compressive strength used for design is based on masonry prism tests in accordance with [Clause 5.1.2](#), the average of any compressive test referred to in [Clause 15.1.1](#) shall not be lower than the masonry unit strength required to obtain the specified prism strength, and no individual test result shall be less than 0.85 of the required unit strength.

Note: *Clause 5.1.2.3 specifies the unit strength to be used.*

6. Frequency of Plant Testing to Determine Specified Compressive Strength

The responsibility to establish and verify the *Specified Compressive Strength* of a CMU understandably rests with the producer of the CMU. Establishing and verifying *Specified Compressive Strength* on an on-going basis requires in-house testing on an on-going basis, with periodic testing of product by an independent agency/laboratory. The latter will generate documentation independent of in-house producer testing, and this documentation is sometimes solicited by designers as an authoritative means to demonstrate strength compliance. Frequency of in-house testing is best directed by the manufacturer, respecting all production issues that would influence compressive strength, including such issues as the various lengths of product runs and changing mix designs.

Periodic independent laboratory testing of samples from the plant, complemented with on-going in-house testing, are effective means of reducing the likelihood of delivering non-compliant, under-strength units to the job site.

Sampling protocol from the plant for both in-house testing and independent laboratory testing must be representative of the finished product so that test results accurately reflect the properties of the population of CMU produced. ASTM C140-03, “*Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units*” requires that the specimens “*be representative of the whole lot of units from which they are selected*”, and further, defines “lot” as “*any number of concrete masonry units of any configuration or dimension manufactured by the producer using the same materials, concrete mix design, manufacturing process and curing method*”.

Previous to the 2004 edition of the CSA A165.1, there were no requirements for test frequency for compressive strength testing by the manufacturer, either in-house or by independent laboratory, and therefore, no requirements for acceptable age of any test data presented to users of the product, including structural engineers and architects. As a first step to address the needs of our designers, the 2004 edition introduced the following requirement for test frequency for compressive strength:

10.4

For a given mix design, compressive strength test data that are used to determine the specified compressive strength of concrete block masonry units in accordance with [Table 1](#) shall be considered representative of units manufactured to the mix design for not more than one year from the date of testing.

Note: *The manufacturer shall have an on-going, in-house quality control program to provide continued assurances of uniformity and acceptability of units manufactured to the mix design.*

Clause 10.4 requires that test data by independent laboratory, used by the producer to establish Specified Compressive Strength, must be not older than one (1) year. The note to this clause recommends that an in-house quality control program should be undertaken by the producer to provide assurance of compliance on an on-going basis.

It is a certainty that the CSA A165.1 Technical Committee will address frequency of test (and age of test data) in the next round of A165.1 development, and it is a certainty that frequency of testing by independent laboratory to establish *Specified Compressive Strength* will be increased.

7. Resolution of On-site Under-Strength Compressive Test Results

By way of Clause 9.1, CSA A165.1-04 references ASTM C 140-03, “*Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units*” as the test standard by which the compressive strength of concrete masonry units must be determined by the producer of CMU. Similarly, by way of D.3.1.2 of CSA S304.1-04, ASTM C140-03 is also referenced for field testing of CMU.

Few test laboratories in Canada are acknowledged by the concrete masonry industry to have the required test equipment, or intimate familiarity with the C140 test protocol. Non-compliant equipment or error in sampling and test procedures may render the test results for compressive strength of CMU invalid.

Where a producer member is notified that field testing has resulted in under-strength units, it is recommended that producer members:

- identify the test laboratory, and request a copy of the test report;
- contrast/compare the results of such testing with in-house quality control reports;
- contact the CCMPA Engineering staff for technical input, intervention where required, and appropriate technical and fact-based resolution.

All correspondence to CCMPA pertaining to this Bulletin shall be direct to:

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