Physical Properties

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4.1 Codes and Standards

In Canada, the material standard used for specifying concrete masonry units is the CSA standard A165 Series, *"CSA Standards on Concrete Masonry Units"*. The Series consists of three standards:

- CSA A165.1, *"Concrete Block Masonry Units"*
- CSA A165.2, *"Concrete Brick Masonry Units"*
- CSA A165.3, *"Prefaced Concrete Masonry Units"*

The CSA A165 Series is a consensus standard written under the auspices of the Canadian Standards Association, a Standards Development Organization (SDO) accredited by the Standards Council of Canada.

For buildings designed in accordance with Part 9 of the National Building Code of Canada (NBCC) (and the Provincial Building Codes for which the NBCC is modeled), the CSA A165 Series is referenced directly for use in Sections 9.15 and 9.20 as the appropriate material standard for concrete masonry units.

For buildings designed in accordance with Part 4 of the NBCC (including Parts 3, 5, and 6), the reference path is not so apparent. Part 4, *"Structural Design"*, references CSA standard S304.1, *"Design of Masonry Structures"*, as the standard for plain and reinforced masonry design. CSA S304.1 requires materials used in masonry construction to comply with CSA A371, *"Masonry Construction for Buildings"*. In accordance with CSA A371, concrete masonry units must comply with the CSA A165 Series of standards, thereby completing the reference link. The CSA A165 Series is consistent with the objectives and intents of the National Building Code of Canada.

The CSA A165 Series is essentially a self-contained material standard, referencing only the following additional consensus standards:

1. for binder materials used in product manufacture:
   a. Cements: CSA A3001, *"Cementitious Materials for Use in Concrete"*
   b. Lime: ASTM C207, *"Standard Specification for Hydrated Lime for Masonry Purposes"*
2. for included aggregates in standard concrete masonry units:
   a. ASTM C331, *"Standard Specification for Lightweight Aggregates for Concrete Masonry Units"*
   b. CSA A23.1, *"Concrete Materials and Methods of Concrete Construction"*
3. for sampling and testing of concrete masonry units:
   a. ASTM C 140, *"Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units"*
   b. ASTM C 426, *"Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units"*.

CSA A165.1, *"Concrete Block Masonry Units"*, contains a set of minimum requirements for concrete block masonry units suitable for both loadbearing and nonloadbearing applications. It is a performance-based standard, neither specifying the method of manufacture nor the specific material contents and mix designs for the units needed to achieve the required performance.

CSA A165.1 identifies a small, yet comprehensive set of unit properties which are known to markedly influence concrete masonry design and construction, and affect the structural performance of constructed concrete block masonry and its durability. It identifies four physical properties, and either further classifies or specifies minimum requirements for each. These properties include:

1. Solid Content;
2. Specified Compressive Strength;
3. Concrete Type (Density and Absorption); and,
4. Moisture Content.

Properties of constructed concrete block masonry which are oftentimes important to building and element design are sometimes expected by users to be contained within the A165.1 standard. These performance considerations usually include:

1. fire resistance;
2. sound control; and,
3. resistance to environmental loads.

Requirements for these are not within the scope of the A165.1 standard. Rather, legislated requirements for these are contained within the Provincial Building Codes which are heavily based upon those in the (model) National Building Code of Canada. For each of these design considerations, other chapters in this Manual discuss the performance of concrete block masonry, and the affect of the concrete block unit on the performance of the masonry. Requirements for thermal performance are not contained within the NBCC, but are legislated by some Provincial Building Codes . Provincial requirements for energy are typically based upon the National Energy Code for Buildings, or ASHRAE 90.1, or both.

Chapter 4 of this Manual will focus exclusively on concrete block masonry units, and standard CSA A165.1.

4.2 CSA A165.1, Concrete Block Masonry Units

4.2.1 Physical Properties of a Masonry Unit

Four physical properties for a concrete block masonry unit are identified by the CSA A165.1 standard:

1. Solid Content;
2. Specified Compressive Strength;
3. Concrete Type (Density and Absorption); and,
4. Moisture Content.

Under the standard, these four properties serve as the basis for classifying a concrete block masonry unit, and for describing and specifying a unit using the facet designation system. This simple and very effective system for specifying concrete block masonry units is introduced and described in Section 4.2.3. Section 4.2.1 provides introductory discussion about each of these four physical properties, and the supporting rationale for the facet designation system.

In accordance with CSA A165.1, the physical properties used by the manufacturer to classify a concrete block masonry unit must:

(a) be representative of the physical properties of the unit at the time of shipment from the place of manufacture;

(b) be established by independent laboratory using the test procedures identified by CSA Standard A165.1; and,

(d) conform to the requirements of Table 1 in CSA Standard A165.1.

4.2.1.1 Solid Content

Concrete block masonry units are classified by solid content , and identified as *hollow, semi-solid, or full solid*.

The standard uses the *gross cross-sectional area*, and the net cross-sectional area of a unit as the basis for determining unit classification by this property. Both are clearly defined by the A165.1 standard and the related CSA masonry standards.

The *gross cross-sectional area* of a unit is the area of masonry on a plane parallel to the bearing surface of the unit, as shown in Figure 4.1. It can be readily determined simply by multiplying the (actual) width x (actual) length of the unit. The *gross cross-sectional area* of a unit is used also in the empirical (structural) design of masonry, under CSA S304.1. It is *not* used by the Limit States Design method of S304.1.

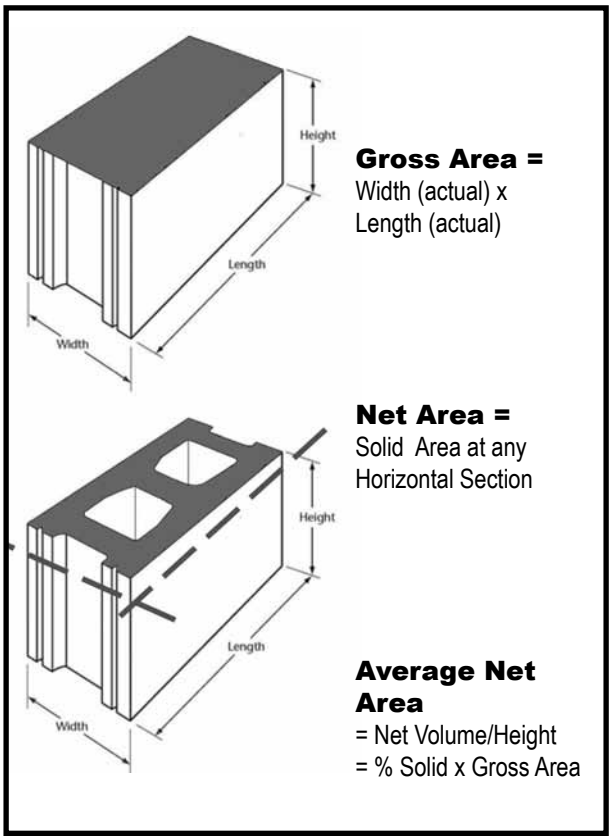
The *net cross-section area* of a unit is the solid area of masonry in *any* plane parallel to the bearing surface of the unit, as illustrated in Figure 4.1. For units having tapered webs and faceshells, the net cross-section area of a unit differs at every horizontal section cut along the height of the unit.

A *hollow unit* has a net cross-sectional area in any plane parallel to the bearing surface of less than 75% of the gross cross-sectional area measured in the same plane. For units having tapered webs and faceshells, the smallest net cross-sectional area is along that plane which includes the least web and faceshell thicknesses, which is the unit's "upper surface as made", or "lower surface as laid".

A *semi-solid unit* has a net cross-sectional area in *all* planes parallel to the bearing surface of at least 75%, and less than 100%, of the gross cross-sectional area measured in the same plane.

A *full solid unit* has a net cross-sectional area in *all* planes parallel to the bearing surface of 100% of the gross cross-sectional area measured in the same plane.

Figure 4.1: *Gross Area, Net Area, and Average Net Area*



Gross Area =
Width (actual) x
Length (actual)

Net Area =
Solid Area at any
Horizontal Section

Average Net Area
= Net Volume/Height
= % Solid x Gross Area

The term *average net cross-sectional area* is also used in CSA A165.1 and other CSA masonry standards including S304.1. It is fully intended to differ from *net cross-sectional area*. To clarify their uses:

(a) Because units other than a full solid unit have tapered webs and faceshells, the net cross-section area of a unit will vary with each horizontal section along the height of the unit. Under the A165.1 standard, the net cross-sectional area of a unit is used exclusively to classify the unit as hollow, semi-solid or full solid, and specifically for this use, it is the least net cross-sectional area of the unit. Net cross-sectional area is not used to determine the solid content of a unit. Indeed, the solid content of a unit is calculated using average net cross-sectional area. In this respect, the physical property of solid content used within CSA A165.1 to classify a concrete masonry unit might be more appropriately termed "minimum net cross-sectional area".

(b) In accordance with CSA A165.1, the average net cross-sectional area of a unit is calculated using the net volume of the unit, typically established by water displacement tests using ASTM C 140. *[The net volume (and thus density) of some concrete block masonry units of Type C or D concretes (described in Section 4.2.1.3) cannot be accurately determined by the ASTM C140 test procedure. It will overestimate the density of such units. As an alternative to using ASTM C140, the net volume may be established using a filler material of steel or lead shot having a diameter of not more than 2 mm. Further, as an alternative to using ASTM C140 or to using spherical filler material to establish unit volume, mould prints available from the manufacturer of the mould used to produce the unit may be used. The mould print will state the volume and solid content of the masonry unit produced from that mould].*

The average net cross-sectional area of a unit is calculated as:

Average net cross-sectional area =
net volume (actual) / height (actual)

Note that the *average net cross-sectional area* is approximately equal to the *net cross-sectional area* measured at mid-height of the unit.

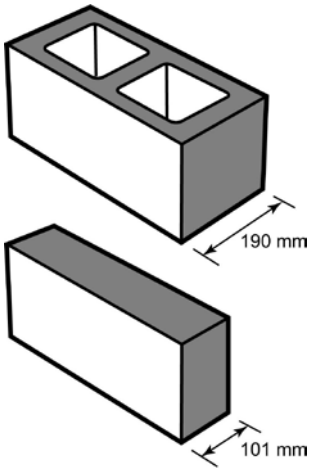
The *average net cross-sectional area* also serves as the basis for determining the specified compressive strength of a unit, which under CSA S304.1, is frequently used to establish the specified compressive strength of the masonry, f'_m, constructed with the unit. It is also used to calculate the solid content of the unit to determine fire resistance rating for concrete block masonry. Fire performance and empirical design of masonry are discussed in Chapters 5 and 8, respectively, of this Manual.

The *equivalent thickness*, t_{ET}, of a concrete masonry unit is the average thickness of solid material in the unit. Alternatively described, it is the resulting width of a concrete block masonry unit if all of its material were cast into a unit without voids (cells and cores) having the same face area (Figure 4.2). It is calculated as:

t_{ET} = (*average net cross-sectional area*) / [length (actual) x height (actual)]

The *solid content* of a unit (or % solid) expresses the equivalent thickness of a concrete block masonry unit as a percentage of the (actual) width of the unit, or similarly, because face

Figure 4.2: *Equivalent Thickness of a Concrete Masonry Unit*



t_{ET} = (*average net cross-sectional area*)/
[length (actual) x height (actual)]

or

t_{ET} = *% solid* x width (actual)

% solid = net volume/gross volume

area remains unchanged, as a ratio of net volume to gross volume (Figure 4.2) (gross volume = actual width x actual height x actual length). Hence,

t_{ET} = % *solid* x width (actual)

or,

% *solid* = t_{ET} / width (actual) = net volume / gross volume

Conveniently, *solid content*, or alternatively, equivalent thickness of a concrete block masonry unit is usually provided to the designer by the producer of that unit. However, it is sometimes necessary to convert between the two.

Example 1: Determining Equivalent Thickness of a Unit

The % *solid* content of a 200 mm hollow concrete block masonry unit is 56%. Its measured (actual) width is recorded as 190 mm. Calculate the equivalent thickness of the unit.

Solution:

Equivalent Thickness = t_{ET} = % solid x (actual) width = 0.56 x 190 mm = 106.4 mm

Example 2: Determining % Solid of a Unit

The *net volume* and *gross volume* of a 150 mm *semi-solid* concrete block masonry unit are determined by test using ASTM C140. They are recorded as 8.443 x 10^6 mm^3 and 10.296 x 10^6 mm^3, respectively. Calculate the % solid of the unit:

Solution:

% *solid* = net volume/gross volume
= 8.443 x 10^6 mm^3 / 10.296 x 10^6 mm^3 = 0.82 = 82%

Hollow units are the most commonly used units for both plain and reinforced masonry because of fewer included materials in manufacture, reduced weight of the unit and of the constructed masonry, ease of handling and laying, ease of placement of bar reinforcement and grout, and generally improved economy. Typically, hollow units have solid contents in the order of 50% to 70%. The lower bound of 50% essentially results from the limits on web and faceshell thicknesses imposed by CSA A165.1 (see Section 3.2.2). The most commonly used hollow units have a solid content of 50 – 60%. These relatively lower solid contents are usually sufficient to meet minimum Sound Transmission Coefficients and Fire Resistance Ratings required by the Building Code for wall assemblies under specific use.

Semi-solid units provide increased thicknesses for webs and faceshells, with resulting higher solid content and consequent larger mortar bedding area (for structural design in accordance with CSA S304.1, this means larger effective cross-sectional area, A_e, and moment of inertia, I_o). Semi-solid units may be selected for plain masonry construction in lieu of hollow masonry units that would otherwise need to be fully or partially grouted, or have cells filled with loose material such as vermiculite or perlite, as required to:

a. increase vertical load carrying capacity and resistance to lateral loads;
b. improve sound or fire performance; or,
c. resist mechanical damage (and improve property and personal protection).

An individual masonry element, such as a wall or column, is usually designed and fully constructed using either hollow or semi-solid units. Note that CSA Standard A371, *"Masonry Construction for Buildings"* requires semi-solid or full solid units in a veneer application.

Full solid units are far less frequently used than hollow units or semi-solid units. Moreover, other than for veneer applications, masonry elements are not often constructed entirely of full solid units. Rather, these units usually serve to complement hollow or semi-solid masonry construction at locations in the masonry element where fully solid construction is needed, yet filling unit cells with grout as a means to achieve this is not desired. For example, this may occur (a) along a bearing course where the constructed element into which the solid units are to be included is otherwise unreinforced (plain) and ungrouted; (b) at courses in the element where air flow vertically through cells of hollow or semi-solid units must be prevented; (c) at courses where drilled-in anchor bolts are placed; or (d) along the top course of an element where the units are exposed to view and must be finished, or increased resistance to water penetration is needed.

4.2.1.2 Specified Compressive Strength of a Masonry Unit

4.2.1.2.1 Use and Significance

Structural Design

Concrete block masonry units are classified by their *specified compressive strength*.

The compressive strength of concrete block masonry units varies principally with the cement and aggregate content, and aggregate type. Typically, unit compressive strengths at 28

days can range from 15 MPa to 40 MPa. The availability of this wide range of unit strengths ensures the economic use of concrete masonry over a wide range of applications.

The *specified compressive strength* of masonry, f'_m, is considered to be the most important property for the structural design of masonry. It is akin to the specified compressive strength of concrete, f'_c, used for the structural design of concrete elements and structures. Within S304.1, the Canadian masonry structural design standard, the specified compressive strength of masonry is related by calculation to other critical engineering properties and behaviours relied upon in masonry design, including masonry shear strength, modulus of elasticity, stiffness, serviceability, and bar reinforcement embedment.

The specified compressive strength of masonry, f'_m, should not be confused with the specified compressive strength of a concrete masonry unit. The compressive strength of a masonry assembly depends on the properties and combined characteristics of the individual materials/components used in its construction, including the mortar, grout, and masonry unit, as well as their configurations. The strength of the masonry assembly is usually less than the strengths of its individual components. And although relationships are complex, very clear and functional relationships exist. Masonry compressive strength and its resulting behaviour can be suitably and reliably predicted by simply using mortar Type, the specified compressive strength of the unit, and presence of grout in the assembly. The affects of workmanship on masonry strength are known and controlled where the masonry is constructed in accordance with CSA A371, *"Masonry Construction for Buildings"*.

The choice of f'_m by designers may vary between structures. However, for a particular structure or masonry element, it is that minimum compressive strength for the masonry upon which structural design calculations are based and upon which the structural designer relies. Hence, the basic concept, and the necessary expectation by the designer, is that the as-constructed strength of the masonry meets or exceeds the specified compressive strength for the masonry stated in the construction documents. And indeed, the material property that is most heavily relied upon to deliver the specified compressive strength of the masonry is the specified compressive strength of the concrete block masonry unit. CSA Standard S304.1 offers two compliance paths to establish the specified compressive strength of the masonry, f'_m, these being: (a) the "Unit and Mortar" method, and (b) the "Prism" method.

Using the "Unit and Mortar" method, the specified compressive strength of concrete block masonry, f'_m, is tabled in CSA Standard S304.1 as a function of: (a) the specified compressive strength of the block unit; (b) the type of mortar intended to be used in the design (Type N or S); and, (c) whether the masonry is hollow (neither solid nor grouted):

Specified Compressive Strength, f'_m, Concrete Block Masonry *(Adapted from Ref. 6)*

Specified compressive strength of unit (average net area)	Type S mortar		Type N mortar	
	Hollow	Solid or Grouted	Hollow	Solid or Grouted
40 or more	22.0	17.0	14.0	10.5
30	17.5	13.5	12.0	9.0
20	13.0	10.0	10.0	7.5
15	9.8	7.5	8.0	6.0
10	6.5	5.0	6.0	4.5

For the constructed masonry, a designer may choose from incremental specified compressive strengths of 10, 15, 20, 30, or greater than 40 MPa (conveniently offered and categorized under A165.1 by the producers of concrete block units), and two mortar Types, either S or N. For example, a specified compressive strength of f'_m = 9.8 MPa would be used for the structural design of hollow concrete block masonry constructed with Type S mortar and concrete block masonry units having a specified compressive strength of not less than 15 MPa. These tabled values are necessarily conservative and represent the lowest end of reported research data. This table conveniently allows a structural designer to quickly establish a design (specified) compressive strength for the masonry, and to readily and prescriptively specify the constituent materials of the masonry, which when constructed in accordance with the requirements of companion CSA masonry standards, will assuredly achieve the required masonry compressive strength. For decades, these data have been used safely and effectively for the structural design of masonry.

By examining the tabled data, a few very useful relationships readily emerge:

1. **Mortar Type** (and therefore mortar compressive strength) has little affect on the specified compressive strength of hollow and grouted concrete block masonry. Under CSA A179, *"Mortar and Grout for Unit Masonry"*, the minimum required field compressive strengths for Type N and Type S mortars are 3.5 MPa and 8.5 MPa, respectively. For hollow masonry constructed with concrete block units

having a 15 MPa specified compressive strength, using the tabled data, it is seen that a mortar strength increase from 3.5 MPa (Type N) to 8.5 MPa (Type S) only marginally increases the specified compressive strength of the masonry, f'_m, from 8 MPa to 9.8 MPa. A 60% decrease in mortar compressive strength results in a strength reduction for the masonry of only about 18%.

2. **Grout strength** has such little significance on the compressive strength of the masonry that, for design, the S304.1 standard does not recognize an increased masonry compressive strength, f'_m, with increased grout strength; such a relationship is not offered in the standard for consideration. Grout compressive strengths in the order of 10 to 12.5 MPa, considered to be relatively "low" by concrete practice, are acknowledged by the A179 and S304.1 standards as sufficient and acceptable. In masonry design and construction, the complete filling of voids intended to be filled is more important to structural performance than high grout compressive strength. [Of course, grouting increases the effective area of masonry which increases its load resistance].
3. **Block strength** significantly affects the compressive strength of the masonry, and except for very high strength units (> 30 MPa), there is a direct and linear relationship between the two properties. As the specified compressive strength of the block unit increases from 15 MPa to 20 MPa (33% increase in block strength), the strength of the masonry using Type S mortar increases: (a) for hollow masonry, from 9.8 MPa to 13 MPa (33%), and (b) for fully grouted masonry, from 7.5 MPa to 10 MPa (33%). By the tabled data, as block strength doubles, so too does the compressive strength of the masonry.

By S304.1, the designer may otherwise use the "Prism" method to establish the specified compressive strength of masonry, f'_m, as an alternative to the "Mortar and Unit" method. By this method, before commencement of the structural design, small masonry assemblies known as prisms are tested in compression using materials intended for the construction. For a given concrete masonry unit specified compressive strength and mortar Type, prism testing invariably increases the design masonry compressive strength above that which is tabled for use by the "Unit and Mortar" method. Notwithstanding this advantage, this method is rarely used because of perceived high cost of testing and scheduling, however, there is a reward obtained in economy of design. To achieve the desired specified masonry compressive strength using this method, the construction will require the use of block units having a specified compressive strength not less than the specified compressive strength of the units used in testing.

Durability

In addition to its importance in the structural design of masonry, the compressive strength of a concrete block masonry unit is also used as a measure of the durability of the unit. Under severe exposure conditions where units are saturated or very nearly saturated with water, and concurrently subjected to repeated cyclical freezing and thawing temperatures, concrete materials are potentially susceptible to deterioration resulting from the freezing expansion of water inside the voids of the unit. Concurrent exposure to de-icing salts will exacerbate this potential.

It is known that the resistance of a masonry unit to these types of deterioration is related to a number of unit properties including its air and compaction void content, density, compressive strength, 24-hrs. absorption, and others. Of these, compressive strength, or other properties related to compressive strength, correlate strongly with resistance. Units offering high compressive strengths with low absorptions show better resistance under severe exposure conditions.

For potential damage to occur, cyclic freezing and thawing conditions and a constant source of moisture must both be present. For typical concrete block masonry structures, vertical surfaces are rarely exposed to such severe conditions. In Canada, units having a compressive strength of not less than 15 MPa have a proven record of good performance in the field when used with appropriate water management strategies and good detailing.

4.2.1.2.2 Sampling and Testing for Unit Compressive Strength

CSA A165.1 references ASTM C 140 as the standardized test method for determining the compressive strength of a unit. By this method, full unit or saw-cut specimens are dried to room temperature and relative humidity, capped on their bedding surfaces with high-strength setting materials in accordance with ASTM C 1552, *"Standard Practice for Capping Concrete Masonry units, Related Units, and Masonry Prisms for Compression Testing",* and tested to failure under concentric compression. Saw-cut specimens, in lieu of full unit specimens, are used where other than a standard concrete masonry unit is tested (a specimen having an unusual size or shape), or where the capacity of the testing machine otherwise may be exceeded.

The *net area compressive strength* of a test specimen is based on the average net area of the specimen and the maximum load it sustains during test, P_{max}. Strength is calculated using the simple engineering principle of load/area:

Net Area Compressive Strength
$= P_{max}$ / *(average net area* of specimen*)*

4.2.1.2.3 Determining the Specified Compressive Strength of a Concrete Block Masonry Unit Under CSA A165.1

The *specified compressive strength* of a concrete block masonry unit is established by the producer of that unit, and is based upon direct testing of the product and subsequent calculation using the test data. It may be reported directly to the structural designer for a particular construction project, or more commonly, it is stated in the technical literature published by the producer.

The structural designer is rarely required to perform the calculations needed to establish the specified compressive strength of a unit. However, an understanding of the basis for its derivation may be needed for a specific project. For example, testing and calculation to establish the specified compressive strength of a unit may be undertaken by the designer where the specified compressive strength of masonry, f'_m, is determined using the prism method under CSA S304.1. Staff at test laboratories must understand both the test and calculation procedures.

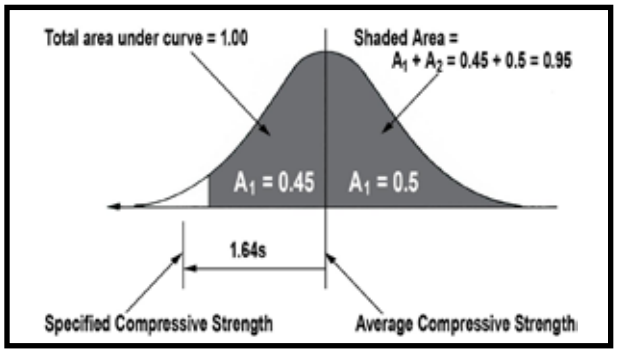
In the design process, the *specified compressive strength* of a concrete block unit is intended to be established before undertaking the structural design of the masonry. For this reason, and to ensure ready availability for the designer, the producer of the concrete masonry unit (pre)establishes the specified compressive strength for masonry products in its inventory.

The specimens selected for compression testing are considered to be representative of the lot of units, that is, to be representative of the unit population. The term lot refers to any number of units of any configuration or dimension manufactured using the same materials, concrete mix design, manufacturing process, and curing method. Under CSA A165.1, to establish the *specified compressive strength* of a *lot*, not less than five specimens must be tested, and not less than 10 specimens must be tested if the coefficient of variation of the test results exceeds 15%. In this manner, CSA A165.1 differs from ASTM C 140 wherein the latter requires 3 specimens only. Typically, the compressive strengths of concrete block units sampled from the same lot show a coefficient of variation significantly less than 15%, and usually less than about 5%.

Consistent with the structural theory of Limit States Design upon which CSA S304.1 is based, the probability of use of under-strength materials in construction must be limited. The objective of CSA A165.1 is to obtain a compressive strength for the masonry unit that will exceed the *specified compressive strength* 95% of the time.

The calculation to determine the *specified compressive strength* of a *lot* of units is based on a standard normal distribution, wherein the area under this distribution curve represents probability of occurrence. The full area under the curve is 1.0 (unitized), and the probability that the compressive strength of a unit will exceed its reported mean (average) strength less 1.64 standard deviations (1.64 s) is 0.95 (*95%*), that is, the unitized area under the curve representing strengths higher than this statistically reduced average strength is 0.95. This is illustrated in Figure 4.3.

Figure 4.3: *Probability of Occurrence of Under-Strength Concrete Block Masonry Units*



In light of this, the *specified compressive strength* of a concrete masonry unit, suitable for use with Limit States Design and based upon tests in accordance with ASTM C 140, is calculated as follows:

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

where

f'_{bl} = specified compressive strength, MPa
f_{av} = mean compressive strength of the test results, MPa
v = coefficient of variation = s/f_{av}

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

where

x = an individual test result
$x_m = f_{av}$ = mean (average) of individual test results
n = number of masonry units tested

Example 3; Calculating the Specified Compressive Strength of Concrete Block Masonry Units

A testing laboratory is conducting compressive strength testing for plant quality control. It determines that five concrete block masonry unit test specimens have average net area compressive strengths of:

1. 11.58 MPa
2. 13.65 MPa
3. 15.51 MPa
4. 10.23 MPa
5. 12.16 MPa

In accordance with CSA A165.1, calculate the specified compressive strength of the units.

Solution:

$f_{av} = x_m =$ mean compressive strength of test results
$f_{av} = x_m =$ (11.58 + 13.65 + 15.51 + 10.23 + 12.16) / n = 63.13 MPa / 5
$f_{av} = x_m =$ 12.63 MPa
$s =$ standard deviation

$$s = \sqrt{\frac{(11.58 - 12.63)^2 + (13.63 - 12.63)^2 + (15.51 - 12.63)^2 + (10.23 - 12.63)^2 + (12.16 - 12.63)^2}{(5 - 1)}}$$

$s =$ 2.02 MPa
$v =$ coefficient of variation = s/f_{av} = 2.02 MPa / 12.63 MPa = 0.16 = 16%

The coefficient of variation exceeds 15%, therefore the specified compressive strength of the unit cannot be determined from the available test results. A total of ten test specimens are therefore required to calculate the specified compressive strength.

Example 4; Calculating the Specified Compressive Strength of Concrete Block Masonry Units

Five concrete block masonry unit test specimens show average net area compressive strengths of:

1. 11.58 MPa
2. 12.15 MPa
3. 11.36 MPa
4. 10.98 MPa
5. 11.63 MPa

In accordance with CSA A165.1, calculate the specified compressive strength of the units.

Solution:

$f_{av} = x_m =$ mean compressive strength of test results
$f_{av} = x_m =$ (11.58 + 12.15 + 11.36 + 10.98 + 11.63) / n = 57.7 MPa / 5
$f_{av} = x_m =$ 11.54 MPa
$s =$ standard deviation

$$s = \sqrt{\frac{(11.58 - 11.54)^2 + (12.15 - 11.54)^2 + (11.36 - 11.54)^2 + (10.98 - 11.54)^2 + (11.63 - 11.54)^2}{(5 - 1)}}$$

$s =$ 0.43 MPa
$v =$ coefficient of variation = s/f_{av} = 0.43 MPa / 11.54 MPa = 0.63 = 3.7%
$f'_{bl} =$ specified compressive strength = $f_{av} - 1.64s$ = 11.54 – (1.64 x 0.43)
$f'_{bl} =$ 10.8 MPa

The specified compressive strength of the units is 10.8 MPa.

4.2.1.2.4 Frequency of Test and Determination of Unit Compressive Strength

Production Testing

The specified compressive strength of a lot is determined periodically by the manufacturer during production of the unit. Required frequency of test by independent laboratory engaged by the producer is prescribed in ASTM C 140. In addition to this, CSA A165.1 limits test frequency by independent laboratory to not less than once per year. In a companion strategy to ensure minimum compressive strengths are achieved during production, and to provide continued assurances of uniformity and acceptability of units manufactured to that mix design, the manufacturers of concrete block masonry units should maintain on-going, in-house quality control programs which include plant testing of units for compressive strength.

Where "special" units are produced using the same materials, mix design, production processes and curing as for standard units, that is, the special units and standard units are from the same lot, the special units are typically considered to have the same material properties (compressive strength, density, absorption, linear drying shrinkage) as those of the standard unit. However, the compressive strength of the special unit itself may differ from that of the standard unit as a consequence of a differing physical configuration.

Course of Construction Testing

Whereas the procedures required by CSA A165.1 are used to determine the specified compressive strength of the masonry unit, they are not the procedures used to verify product strength compliance, on-site, during course of construction.

Test requirements to verify unit compressive strength during course of construction are contained in CSA S304.1. They are intended to be separate and distinct from the pre-construction (production) test requirements respected by producers in CSA A165.1.

Like pre-construction testing, field testing for compressive strength uses the sampling and testing procedures of ASTM C 140. However, unlike pre-construction testing, a "specified compressive strength" of the sampled units is not calculated. To establish compliance, the average compressive strength of five test samples must be not less than the stated specified compressive strength. Additionally, no individual test result may be less than 85% of the unit specified compressive strength.

Example 5; Establish Course of Construction Compliance for Compressive Strength

Five concrete block masonry units are sampled from a construction site. The test specimens show average net area compressive strengths of:

1. 15.78 MPa
2. 16.32 MPa
3. 16.85 MPa
4. 15.13 MPa
5. 12.57 MPa

The specified compressive strength for the units is 15 MPa. Using the requirements stated in CSA S304.1, determine if these units satisfy the strength specification.

Solution:

f_a= x = (15.78 + 16.32 + 16.85 + 15.13 + 12.57) / n = 76.65 MPa / 5

f_{av} = 15.33 MPa

x_5 = 12.57 / 15.0 = 0.838

Whereas the average compressive strength of the five samples exceeds the 15 MPa specified compressive strength, the strength of Sample 5 is less than 85% of the specified compressive strength. Therefore, these units do not comply with the specifications.

Requirements for test frequency during course of construction are also contained in CSA S304.1. Additionally, by S304.1, field control testing of units may be waived at the discretion of the designer where the specified compressive strength for the units used in design of the masonry is not greater than 15 MPa. A 15 MPa unit specified compressive strength is used for the vast majority of construction in Canada.

4.2.1.2.5 Visually Identifying the Specified Compressive Strength of a Unit

It is common practice in many areas of Canada to place "stickers" on the shrink-wrap around block pallets to identify block size, specified compressive strength, and any other important property particular to the unit. This is done to readily identify inventory at the producer's storage yard, and to ensure that the correct units are shipped to the construction site.

On the construction site, after the units are de-palletized, it is not possible to visually identify the compressive strength of a concrete block unit without an individual marking. A 15 MPa unit and a 25 MPa unit may appear identical.

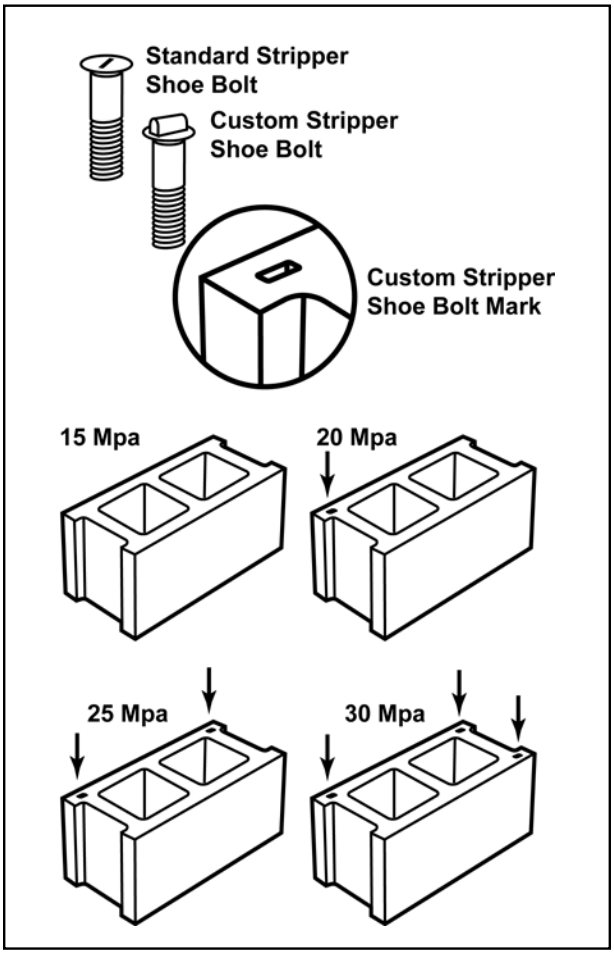
By individually marking each block unit, the likelihood is increased that the specified compressive strength of the installed unit is correctly matched by the mason to the unit specified compressive strength required for the masonry ele-

ment. High strength units will be installed in those masonry elements required to have high strength units, and this is particularly important where mixed strength units are used on a site for economy of design and construction.

To this end, CSA A165.1 requires individual marking of concrete block masonry units. Each unit having a specified compressive strength greater than 15 MPa must have its strength identified on one or more of its surfaces. On-site inspection and verification is simplified and economized. 15 MPa units are the standard units for design and construction and are excluded from this requirement.

Although unit markings have not been standardized in CSA A165.1, the producer members of CCMPA use the identification system shown in Figure 4.4.

Figure 4.4: *Unit Marking for Specified Compressive Strength; Adopted by CCMPA*



4.2.1.3 Concrete Type

Concrete block masonry units are classified by their concrete type, and this is related to their density and absorption.

Unit Density

Concrete type is established knowing the oven-dry density of the concrete used in the manufacture of a unit. Oven-dry density is determined by test in accordance with ASTM C 140. Concrete type might be otherwise, and more appropriately termed density classification in CSA A165.1. This would eliminate a need to differentiate "concrete type" used by CSA A165.1 from this same term yet (slightly) different property used by the National Building Code of Canada to establish the fire-resistance rating of concrete block masonry and concrete (Chapter 5).

CSA A165.1 quantitatively identifies (essentially) four concrete types (or density classifications), however, in construction practice, these concrete types are more so identified simply by name, as follows:

Concrete Type	Concrete Density	Common Construction Name
A	Over 2000 kg/m^3	Normal-weight
B	1800 to 2000 kg/m^3	Medium-weight
C	1700 to 1800 kg/m^3	Medium-weight, or Semi-Light-weight
D	Less than 1700 kg/m^3	Light-weight
N	No limits	

Concrete type is a direct result of the type of aggregate used in the manufacture of the unit. In fact, the common terms "normal-weight" and "light-weight" are derived from the density of the aggregates. Typically, sand and gravel and crushed stone are used as normal-weight aggregates, and expanded shale and clay or other naturally-occurring materials are used as light-weight aggregates. Medium-weight units are produced by using various blends of these light-weight and normal-weight aggregates. Specifications for aggregates are covered

in CAN/CSA A23.1 for normal-weight and ASTM C 331 for light-weight materials.

NCMA Tek 2-6, "*Density-Related Properties of Concrete Masonry Assemblies*" provides an excellent treatise on the various unit and masonry properties influenced by unit density, and provides references for additional reading. It is important to note that, with some exceptions, the various classifications for specified compressive strength in A165.1 can all be met by normal-weight, medium-weight, and light-weight product through adjustments in mix-design. The density of lighter-weight concrete block masonry units generally increases with increasing compressive strength. Concrete block masonry units with specified strengths greater than 20 MPa may not be available in type C and D concrete.

Use of a particular aggregate type by a manufacturer is locally dependent upon its availability. Normal-weight units are commonly used by block manufacturers in eastern Canada, whereas light-weight units are typical in western Canada. Medium-weight units produced in Canada usually fall within the 1700 to 1800 kg/m^3 density classification, but not so for all regions. Choice of density by the designer depends upon availability and the required properties for the masonry. Choice is rarely related to achieving a certain specified compressive strength, and most often is related to requirements for fire and sound control (see Chapters 5 and 7 of this Manual; for a given density, the solid content of a unit can be varied in order to meet requirements for fire and sound). A designer should contact local producers for availability before specifying a particular concrete type.

The individual weight of a concrete masonry unit is influenced by its concrete type, and its net volume [= (actual) width x solid content].

Typically, manufacturers provide information on the exact densities and weights of their products.

Unit Absorption

Under A165.1, maximum permissible water absorption is assigned to each concrete type. Absorption is determined by test in accordance with ASTM C 140, and is calculated from the weight per unit volume difference between saturated and oven-dry units. It is a measure of the total water absorbed by a unit following 24 hrs. of immersion (with nominal head pressure), and therefore, it is a measure of the voids (reachable pore volume) within the net volume of the concrete, including the voids within the aggregate itself.

The 24-hr. absorption differs from rate of absorption (or initial rate of absorption, IRA), which is a property measured by standardized test for clay masonry products. No such standardized test exists for concrete masonry products.

Under CSA A165.1, the following maximum absorption limits are assigned to each concrete density:

Concrete Type	Concrete Density	Maximum Absorption Limit
A	Over 2000 kg/m^3	175 kg/m^3
B	1800 to 2000 kg/m^3	200 kg/m^3
C	1700 to 1800 kg/m^3	225 kg/m^3
D	Less than 1700 kg/m^3	300 kg/m^3
N	No limits	No Limits

These limits are related to a measure of compaction of the unit during manufacture and its void space. The absorption test measures voids within the aggregates themselves as well as the surrounding cement paste. Because light-weight aggregates contain greater void space than normal-weight aggregates, a lower-density classification is permitted a higher absorption value than a higher density classification for the same level of compaction.

The absorption of a unit, like its compressive strength, is used as an indicator of its resistance to freeze/thaw deterioration. In lieu of conducting direct freeze/thaw test on units, these properties serve as surrogate predictors of resistance. Segmental Retaining Wall (SRW) units, which are dry-cast cementitious units similar to concrete

block masonry units and oftentimes manufactured by the same producers, are readily exposed to water, snow, ice, soil and salt and serve in markedly more severe exposure environments than concrete block masonry units included in building structures. Field and laboratory research on SRW units shows that units offering high compressive strengths and high density with low absorptions generally show better resistance under severe exposure conditions.

The limits on 24-hr. absorption stated in A165.1 for concrete block masonry units have been used for decades. Compliant units have a proven record of good performance in Canadian building construction. This suggests that these limits indeed are below the threshold values needed for the exposure environments to which concrete block masonry is typically subjected.

The stated absorption limits are sometimes misunderstood by users to be a measure of in-service water penetration resistance for masonry units. The higher absorption limits permitted for lower density concrete block masonry units are in no manner intended to imply that masonry constructed with lower density units offers comparatively less resistance to water penetration.

4.2.1.4 Moisture Content

Concrete block masonry units are classified by their *moisture content*, and this is related to their *linear shrinkage* characteristics.

Concrete loses or absorbs moisture with changes in the moisture content or relative humidity of the surrounding air. The cement paste may gain moisture and hence "swell", or lose moisture and "shrink" before it attains an air dry equilibrium condition. It will undergo no dimensional change when the moisture content of the concrete is in equilibrium with the relative humidity of the surrounding environment.

ASTM C426, "*Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units*" is referenced by CSA A165.1. It is the standard test method used to determine the total change in linear dimension of a concrete block masonry unit as it dries from a saturated condition to an oven-dry weight and length under accelerated drying conditions. These conditions are intended to replicate the set of drying conditions representative of concrete masonry service environments in Canada. Of course, neither extreme is met in service. Masonry units are never delivered to a construction site in a saturated condition, and moreover, could not be laid in this condition.

If unacceptably moist units are laid in a wall at the time of construction, and this inherent shrinkage is restrained in-service, stresses are developed within the masonry that may cause cracking, and this may be detrimental to the required performance of the masonry. One solution to minimizing the likelihood of cracking associated with unit moisture volume change is to require all or some shrinkage of the units to take place before they are laid, so that their residual, in-the-wall movement is suitably limited.

Because atmospheric humidity can be continually changing, particularly for exterior exposures, the moisture content of concrete is similarly affected and is constantly varying in an attempt to remain in balance. The practical approach to limiting volume change of the unit once included in a wall is to supply concrete masonry units that are dried to a moisture level in equilibrium with a relative humidity at least as low as the average for the particular location and intended service. After being laid, higher and lower humidity levels may then produce some volume change and stresses, but these will disappear when the relative humidity returns to a "normal" condition.

This solution offered for concrete masonry moisture volume change is the solution upon which CSA A165.1 is based. By this standard, linear shrinkage for concrete block masonry units, expressed as a percentage of their initial (moisture saturated) length, are grouped into three shrinkage classifications. This grouping is somewhat arbitrary and is not intended to suggest shrinkage limits, or to suggest that units having lower characteristic shrinkage are preferable. For each shrinkage classification, a limit on moisture content for the unit is stated, expressed as a percent of the 24-hr. absorption of the unit. The stated limits with CSA A165.1 depend upon the relative humidity (RH) of the intended service environment:

Maximum Moisture Contents for Concrete Block Masonry Units *(Adapted from Ref. 3)*

The limits on moisture content vary according to the shrinkage characteristics of the unit. The values have been chosen to equalize the potential for residual shrinkage among the three linear shrinkage classifications. These limits represent the needed amount of drying or preconditioning of a unit. For a given service environment (RH), units having a greater total linear drying shrinkage must be relatively drier at the time of delivery to a construction site. Similarly, units must be relatively drier when delivered to service environments having a lower RH. As a point of clarification, a stated relative humidity actually refers to the humidity at point of manufacture of the unit, and not to the RH at a construction site. In Canada, units are manufactured for local markets, and there is an inherent assumption that the RH at point of manufacture does not differ significantly from say, RH of in-service exterior exposure.

	Maximum Moisture Content (% of Total Absorption)	
Linear Shrinkage, %	**RH over 75%**	**RH under 75%**
< 0.03	45	40
0.03 to 0.045	40	35
> 0.045	35	30

In order to determine the maximum permissible moisture content for a concrete block masonry unit using CSA A165.1, the manufacturer must know the total linear shrinkage of the unit produced, and the mean relative humidity condition at the point of manufacture. The latter is obtained from mean annual relative humidity data gathered by the weather office, which is frequently tabled or presented in map form by Environment Canada. The former is determined by test using ASTM C 426, with sampling of units and frequency of testing in accordance with ASTM C 140.

Units which satisfy the requirements for moisture content are referred to as moisture controlled units, although this term is not specifically defined by the A165.1 standard. These units are identified by the facet designation system as “M” units (see 4.2.3). Moisture controlled units are typically specified by a designer where large fluctuations in moisture and RH are anticipated for the service environment, such as for exterior exposures.

Units which do not necessarily satisfy the requirements for moisture content are termed *non-moisture controlled* units, and alternatively, these too may be specified by a designer. These units are identified by the facet designation system as “O” units (see 4.2.3). For interior partitions, and for the inner wythes of cavity walls that are suitably protected from moisture from the exterior by an air/vapour barrier membrane, specifying moisture controlled units may be unnecessary.

Drying of concrete masonry units does not improve the moisture-volume stability if the units are wetted prior to use. Where moisture controlled units are specified, protection from rain and other moisture sources must be provided for the units both by the manufacturer and mason so that the pre-conditioned moisture content remains relatively unaffected before the units are laid.

Limiting the residual shrinkage of concrete block masonry units is only one of several means available to a designer to limit masonry movement, and the differential movement between masonry and adjacent elements. Movement is the result of a number of deformations usually acting in combination and is not attributable to shrinkage movement alone. Shrinkage is not necessarily the largest contributor of movement for a given service environment. In Canada, it is probable that wall thermal movements are greater than shrinkage movements under exterior exposures.

Limits on moisture content establish predictable shrinkage characteristics for the masonry so that required frequency of placement of movement joints in a structure can be thoughtfully considered by a designer. CSA S304.1 provides guidance for the calculation of reasonably anticipated in-service movements in concrete block masonry. The NCMA Tek 10 Series (Ref. 8) series offers both an empirical and engineered approach to movement joint placement in concrete block masonry construction.

4.2.2 The Facet Designation System for Specifying Concrete Masonry Units Under CSA A165.1

The facet designation system is unique to the CSA A165 Series. It is a convenient and simple means for users to specify the desired properties of a concrete block masonry unit needed for a particular application.

As its basis, the facet designation system uses each of the four physical properties identified in the A165.1 standard. These four physical properties, which include (a) solid content, (b) specified compressive strength, (c) concrete type, and (d) moisture content are described at length in Section 4.2.1 of this Manual. Each property is represented by a facet. Each facet is assigned various symbols. Each symbol within a facet represents a particular sub-property or identification for the unit. Table 1 in CSA A165.1, "Physical Properties", identifies facet, symbol, and property, and serves as the basis for the facet designation system. To demonstrate its use, Table 1 is adapted and presented below.

To fully classify, and therefore fully specify a concrete block masonry unit, all four facets must be used by assigning that symbol to each property which represents the sub-property of choice for design.

Example 6: Using the Facet Designation System

Specify a concrete block masonry unit using the facet designation system, having the following properties:

- semi-solid;
- specified compressive strength of 20 MPa;
- concrete type, having density between 1700 and 1800 kg/m^3;
- non-moisture controlled.

Solution:

SS/20/C/O

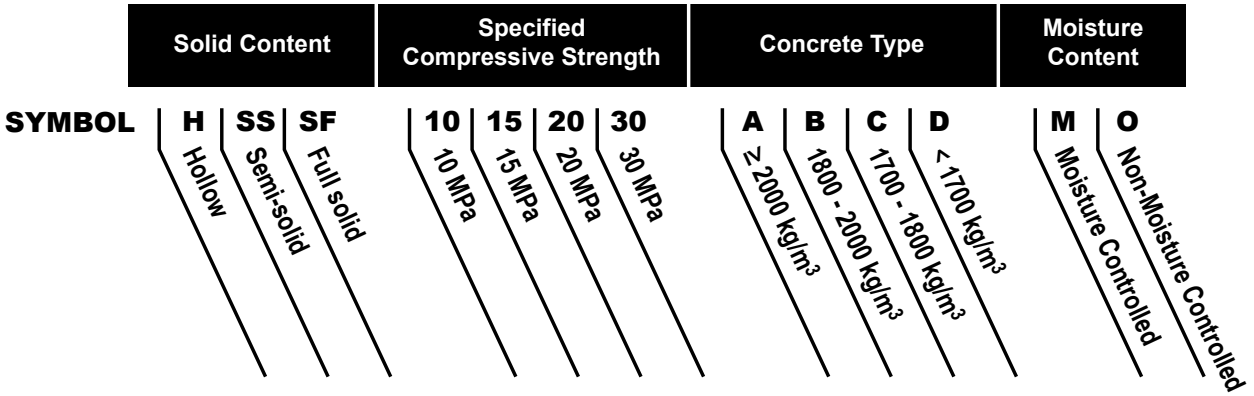
The specified physical properties for the unit apply at the point of manufacture and at the time of shipment by the manufacturer.

Whereas multiple combinations are possible under the facet designation system, a manufacturer may not produce all of the various units needed to meet all of the various combinations. However, a manufacturer is typically positioned to produce a wide range of product, sufficient to allow a designer to select a unit that will satisfy a particular design need.

4.2.3 Dimensional Tolerances of a Standard Concrete Block Masonry Unit

Clause 7 of CSA A165.1 places limits on the permissible variations in the dimensions of standard concrete block masonry units. These limits facilitate laying of the units, assist the mason to construct the masonry within the suitable tolerances identified under CSA A371, and help to offer an aesthetic finish and appearance of the constructed masonry by limiting faceting and offsets between arrises of adjacent units (due to unit manufacture).

FACET (Physical Properties, Table 1, CSA A165.1)



CSA A165.1 limits the dimensional tolerances on standard concrete block masonry units to:

1. Width: ±2 mm;
2. Height: +2 mm, -3 mm
3. Length: ±3 mm.

These provide a tolerance envelope in unit size, within which deviations in "out-of-square and warpage" and "within job lots" are permitted:

1. in warpage and out-of-square, dimensional variations must not exceed 2 mm; and,
2. within a job lot, the maximum variation between units of a specified dimension must not exceed 2 mm.

Although the term "job lot" is not defined in CSA A165.1, it is understood to be a lot intended for use on a specific job (or project) consisting of units having the same configuration, solid content, and nominal dimensions, including intended colour and finish.

Further to the stated limits on standard units within a job lot:

(1) For masonry elements where units from one job lot are necessarily combined with units from a different job lot, their suitability for use must be assessed. For example, where special units are to be included within a masonry element constructed of standard units, before laying the units, the dimensions of the special units should be gauged for suitability of use with the standard units.

(2) There are practical limits on the number of units within a job lot. Sourcing from a single lot or job lot may not be feasible over a prolonged time period. Where considerable time has passed before work recommences on a partially constructed masonry element, or before work commences on a masonry element that junctions with masonry elements constructed earlier, before laying the units, the dimensions of the units should be gauged for suitability of use with the existing.

Note that these dimensional tolerances pertain to standard concrete block masonry units. For standard units intended for architectural applications, tighter unit dimensional tolerances may be needed, and tolerances that must necessarily differ from those stated in CSA A165.1 should be stated in project specifications. Dimensional tolerances achievable for architectural units are not stated in CSA A165.1; these may vary with the unit type and between manufacturers.

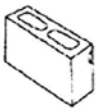
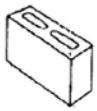
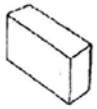
4.3 Physical Properties of Concrete Block Masonry Units

Table 4.1 offers physical property data for standard concrete block masonry units that comply with the requirements of CSA A165.1. These data are representative of typical product manufactured by producer members of the Canadian Concrete Masonry Producers Association.

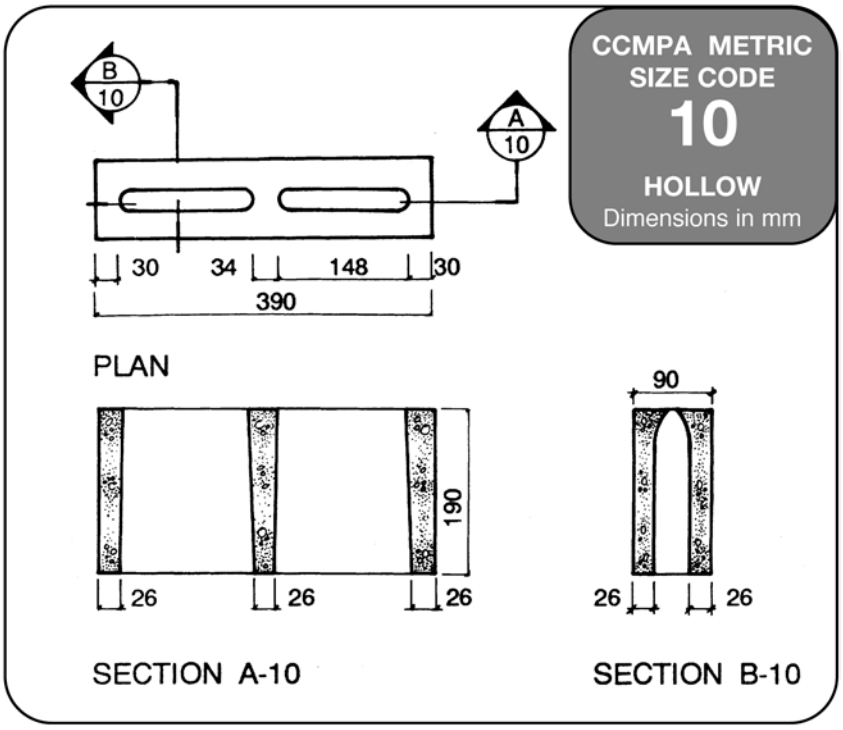
4.4 References

1. ASTM International, "Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units", ASTM C 140, ASTM, Philadelphia, USA, 2003.
2. ASTM International, "Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units" ASTM C 426, , Philadelphia, USA, 2003.
3. Canadian Standards Association, CSA A165.1 "Concrete Block Masonry Units", CSA A165 Series, CSA, Mississauga, Ontario, Canada, 2004.
4. Canadian Standards Association, CSA A179 "Mortar and Grout for Unit Masonry", CSA A179, CSA, Mississauga, Ontario, Canada, 2004.
5. Canadian Standards Association, CSA A371, "Masonry Construction for Buildings", CSA, Mississauga, Ontario, Canada, 2004.
6. Canadian Standards Association, CSA S304.1, "Design of Masonry Structures", CSA, Mississauga, Ontario, Canada, 2004.
7. National Concrete Masonry Association, "Tek 2-6 Density-Related Properties of Concrete Masonry Assemblies", National Concrete Masonry Association, Herndon, Virginia, USA, 2008.
8. National Concrete Masonry Association, "Tek 10 Series, Movement Control", National Concrete Masonry Association, Herndon, Virginia, USA..

4.1 The Physical Properties of Standard Metric Size Block

PHYSICAL PROPERTIES OF STANDARD METRIC SIZE BLOCK			SIZE CODE 10		
ACTUAL DIMENSIONS (mm) Width 90 Length 390 Height 190		NOTES*	STANDARD CONFIGURATION HOLLOW	75% SOLID	SOLID
PROPERTIES					
Dimensions (mm)	Minimum Faceshell Thickness	1	26	30	N/A
	Minimum Web Thickness	1	26	26	N/A
	Equivalent thickness	2	66	74	90
Area (mm^2)	Gross Cross-sectional Area	3	3.51×10^4	3.51×10^4	3.51×10^4
	Net Cross-sectional Area	4	2.56×10^4	2.88×10^4	3.51×10^4
	Cell (Core) Area	5	4.75×10^3	3.15×10^3	N/A
Volume (mm^3)	Gross Volume	6	6.669×10^6	6.669×10^6	6.669×10^6
	Net Volume	7	4.868×10^6	5.469×10^6	6.669×10^6
Percentage Solid	Net Volume/Gross Volume		73%	82%	100%
Typical Unit Mass (kg)	CSA "A" – Type "A" Concrete (2100 kg/m^3)	8	10.2	11.5	14
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		9.2	10.4	12.7
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		8.5	9.7	11.7
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		8	9	11
Typical Wall Mass (kg/m^2) (with Mortar)	CSA "A" – Type "A" Concrete (2100 kg/m^3)		138	155	189
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		125	140	171
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		115	130	158
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		109	122	149
(Minimum) Specified Compressive Strength (MPa)	Based on Net Area		15	15	15
	Based on Gross Area		10.95	12.3	15
Fire Resistance Rating (hours)	S or N of NBCC (Normal Weight)	9	0.8	1.1	1.4
	$L_2$20S of NBCC (Light Weight)		1.1	1.3	1.8
Sound Properties	Sound Transmission Class (STC)	10			
	- CSA Type "A", "B" Concrete		43	45	47
	- CSA Type "C", "D" Concrete		40	42	45
Thermal Properties (m^2 °C/W)	RSI Factors	11			
	- CSA Type "A", "B" Concrete		0.17	N/A	N/A
	- CSA Type "C", "D" Concrete		0.24	N/A	N/A
Moment of Inertia (mm^4)	Per Block, I		22.69×10^6	23.25×10^6	23.69×10^6
	Per Metre, I_m		58.18×10^6	59.61×10^6	60.75×10^6
Section Modulus (mm^3)	Per Block, S		0.504×10^6	0.517×10^6	0.527×10^6
	Per Metre, S_m		1.293×10^6	1.324×10^6	1.350×10^6

* Information to be used in conjunction with explanatory notes on Page 4-26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SIZE CODE
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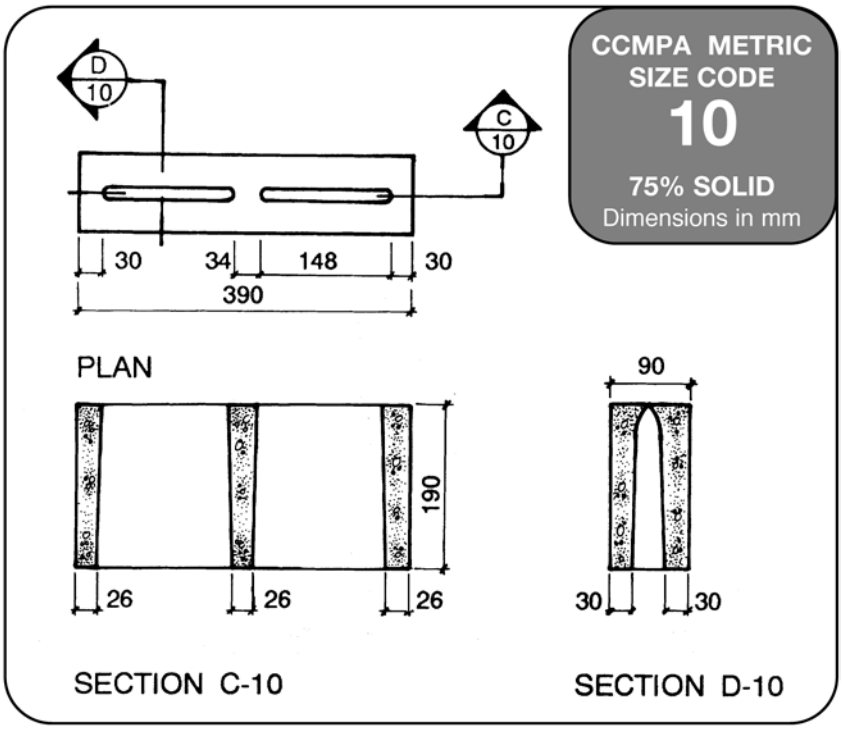
SECTION A-10
SECTION B-10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10
C
10
CCMPA METRIC
SIZE CODE
10
75% SOLID
Dimensions in mm
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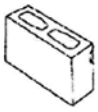
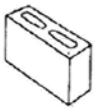
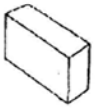
34
148
30
390
PLAN
90
190
26
26
26
30
30
SECTION C-10
SECTION D-10

Physical Properties

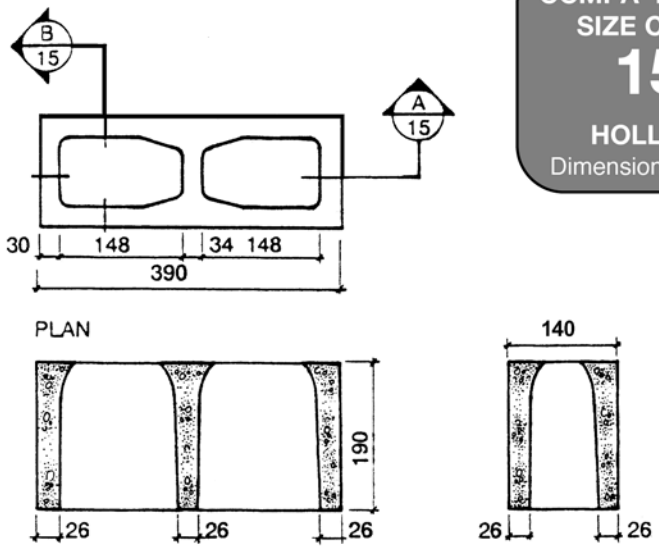
PHYSICAL PROPERTIES OF STANDARD METRIC SIZE BLOCK

SIZE CODE 15

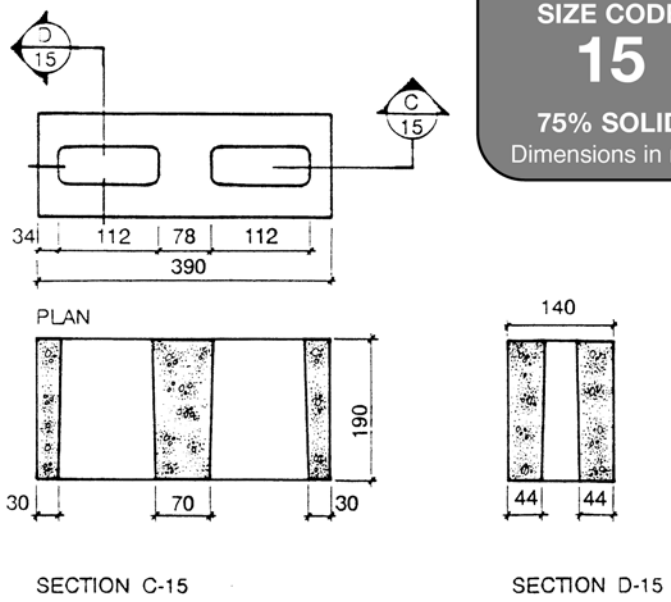
ACTUAL DIMENSIONS (mm) Width 140 Length 390 Height 190		NOTES*	STANDARD CONFIGURATION		
PROPERTIES			HOLLOW	75% SOLID	SOLID
					
Dimensions (mm)	Minimum Faceshell Thickness	1	26	44	N/A
	Minimum Web Thickness	1	26	30	N/A
	Equivalent thickness	2	81	112	140
Area (mm^2)	Gross Cross-sectional Area	3	5.46×10^4	5.46×10^4	5.46×10^4
	Net Cross-sectional Area	4	3.17×10^4	4.37×10^4	5.46×10^4
	Cell (Core) Area	5	1.145×10^4	5.45×10^3	N/A
Volume (mm^3)	Gross Volume	6	10.374×10^6	10.374×10^6	10.374×10^6
	Net Volume	7	6.017×10^6	8.299×10^6	10.374×10^6
Percentage Solid	Net Volume/Gross Volume		58%	80%	100%
Typical Unit Mass (kg)	CSA "A" – Type "A" Concrete (2100 kg/m^3)	8	12.6	17.4	21.8
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		11.4	15.8	19.7
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		10.5	14.5	18.2
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		9.9	13.7	17.1
Typical Wall Mass (kg/m^2) (with Mortar)	CSA "A" – Type "A" Concrete (2100 kg/m^3)		170	235	294
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		154	213	266
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		142	196	245
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		134	185	231
(Minimum) Specified Compressive Strength (MPa)	Based on Net Area		15	15	15
	Based on Gross Area		8.7	12	15
Fire Resistance Rating (hours)	S or N of NBCC (Normal Weight)	9	1.1	2	2.9
	$L_2$20S of NBCC (Light Weight)		1.5	2.8	4+
Sound Properties	Sound Transmission Class (STC)	10			
	- CSA Type "A", "B" Concrete		46	50	52
	- CSA Type "C", "D" Concrete		43	47	50
Thermal Properties (m^2 °C/W)	RSI Factors	11			
	- CSA Type "A", "B" Concrete		0.19	N/A	N/A
	- CSA Type "C", "D" Concrete		0.03	N/A	N/A
Moment of Inertia (mm^4)	Per Block, I		74.07×10^6	86.86×10^6	89.18×10^6
	Per Metre, I_m		189.9×10^6	222.7×10^6	228.7×10^6
Section Modulus (mm^3)	Per Block, S		1.058×10^6	1.241×10^6	1.274×10^6
	Per Metre, S_m		2.713×10^6	3.182×10^6	3.267×10^6

* Information to be used in conjunction with explanatory notes on Page 4-26

CCMPA METRIC SIZE CODE
15
HOLLOW
Dimensions in mm



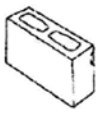
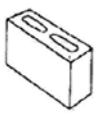
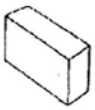
CCMPA METRIC SIZE CODE
15
75% SOLID
Dimensions in mm



Physical Properties

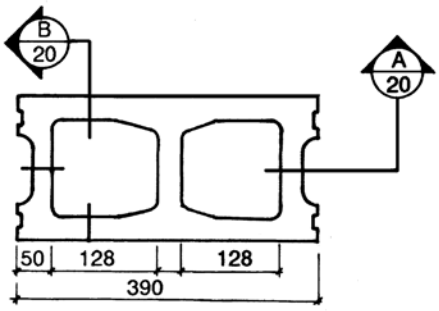
PHYSICAL PROPERTIES OF STANDARD METRIC SIZE BLOCK

SIZE CODE 20

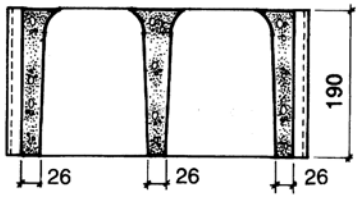
ACTUAL DIMENSIONS (mm) Width 190 Length 390 Height 190		NOTES*	STANDARD CONFIGURATION		
PROPERTIES			HOLLOW	75% SOLID	SOLID
					
Dimensions (mm)	Minimum Faceshell Thickness	1	32	60	N/A
	Minimum Web Thickness	1	26	30	N/A
	Equivalent thickness	2	106	148	190
Area (mm^2)	Gross Cross-sectional Area	3	7.41×10^4	7.41×10^4	7.41×10^4
	Net Cross-sectional Area	4	4.15×10^4	5.78×10^4	7.41×10^4
	Cell (Core) Area	5	1.53×10^4	6.75×10^3	N/A
Volume (mm^3)	Gross Volume	6	14.08×10^6	14.08×10^6	14.08×10^6
	Net Volume	7	7.88×10^6	10.97×10^6	14.08×10^6
Percentage Solid	Net Volume/Gross Volume		56%	78%	100%
Typical Unit Mass (kg)	CSA "A" – Type "A" Concrete (2100 kg/m^3)	8	16.6	23	29.6
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		15	20.9	26.8
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		13.8	19.2	24.6
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		13	18.2	23.3
Typical Wall Mass (kg/m^2) (with Mortar)	CSA "A" – Type "A" Concrete (2100 kg/m^3)		223	311	399
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		202	282	361
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		186	259	333
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		176	245	314
(Minimum) Specified Compressive Strength (MPa)	Based on Net Area		15	15	15
	Based on Gross Area		8.4	11.7	15
Fire Resistance Rating (hours)	S or N of NBCC (Normal Weight)	9	1.8	3.2	4+
	$L_2$20S of NBCC (Light Weight)		2.5	4+	4+
Sound Properties	Sound Transmission Class (STC)	10			
	- CSA Type "A", "B" Concrete		50	53	56
	- CSA Type "C", "D" Concrete		46	51	53
Thermal Properties (m^2 °C/W)	RSI Factors	11			
	- CSA Type "A", "B" Concrete		0.21	N/A	N/A
	- CSA Type "C", "D" Concrete		0.32	N/A	N/A
Moment of Inertia (mm^4)	Per Block, I		194.2×10^6	217.1×10^6	222.9×10^6
	Per Metre, I_m		498.0×10^6	556.6×10^6	571.6×10^6
Section Modulus (mm^3)	Per Block, S		2.045×10^6	2.285×10^6	2.347×10^6
	Per Metre, S_m		5.242×10^6	5.859×10^6	6.017×10^6

* Information to be used in conjunction with explanatory notes on Page 4-26

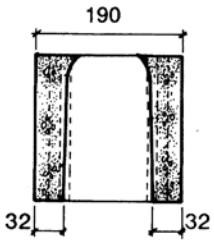
CCMPA METRIC SIZE CODE
20
HOLLOW
Dimensions in mm



PLAN

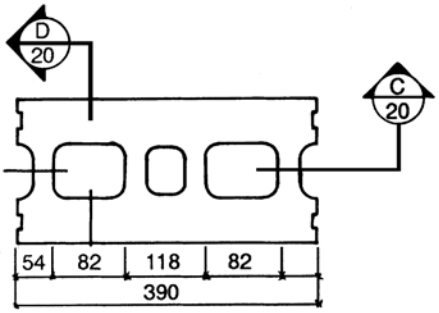


SECTION A-20

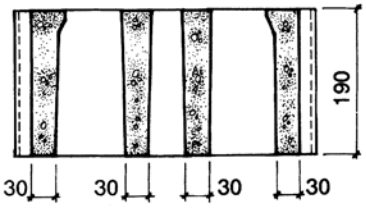


SECTION B-20

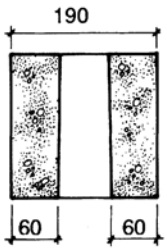
CCMPA METRIC SIZE CODE
20
75% SOLID
Dimensions in mm



PLAN



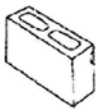
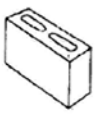
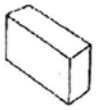
SECTION C-20



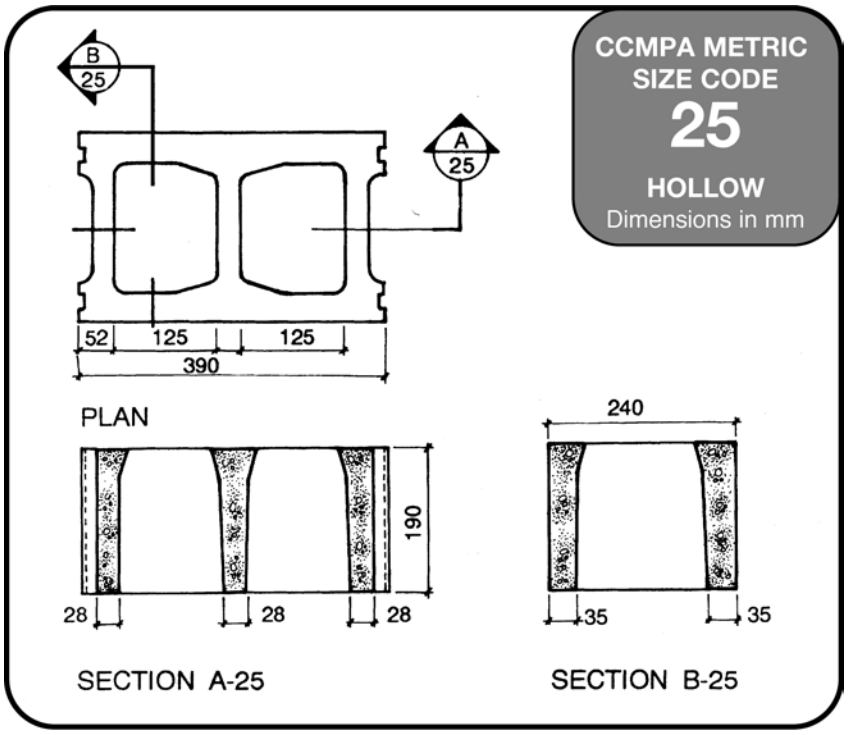
SECTION D-20

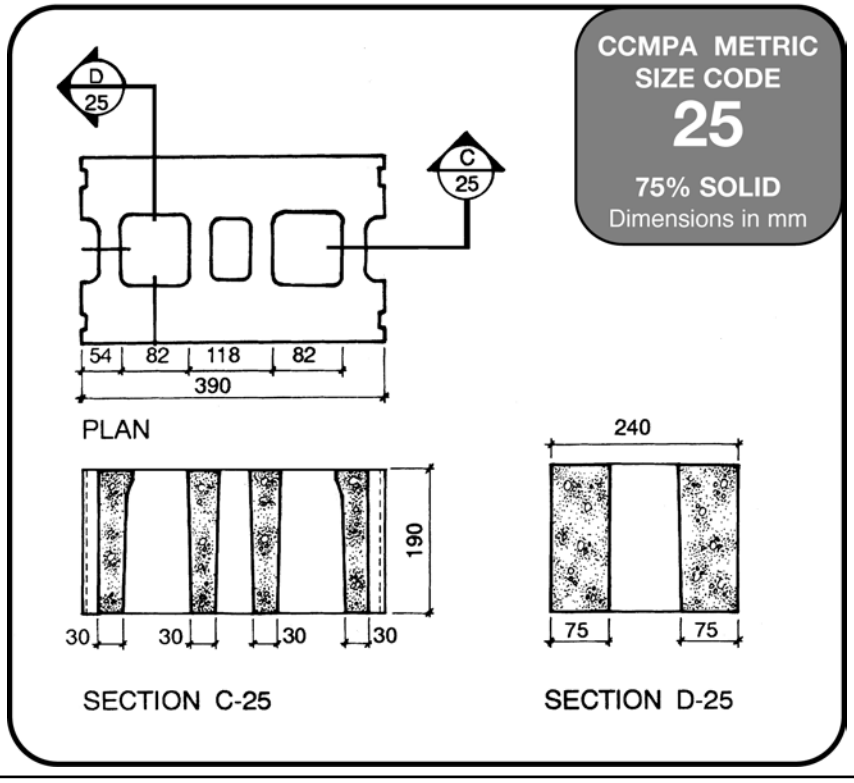
PHYSICAL PROPERTIES OF STANDARD METRIC SIZE BLOCK

SIZE CODE 25

ACTUAL DIMENSIONS (mm) Width 240 Length 390 Height 190		NOTES*	STANDARD CONFIGURATION		
PROPERTIES			HOLLOW	75% SOLID	SOLID
					
Dimensions (mm)	Minimum Faceshell Thickness	1	35	75	N/A
	Minimum Web Thickness	1	28	30	N/A
	Equivalent thickness	2	127	187	240
Area (mm^2)	Gross Cross-sectional Area	3	9.36×10^4	9.36×10^4	9.36×10^4
	Net Cross-sectional Area	4	4.96×10^4	7.30×10^4	9.36×10^4
	Cell (Core) Area	5	2.06×10^4	8.80×10^3	N/A
Volume (mm^3)	Gross Volume	6	17.784×10^6	17.784×10^6	17.784×10^6
	Net Volume	7	9.43×10^6	13.87×10^6	17.784×10^6
Percentage Solid	Net Volume/Gross Volume		53%	78%	100%
Typical Unit Mass (kg)	CSA "A" – Type "A" Concrete (2100 kg/m^3)	8	19.8	29.2	37.3
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		17.9	26.4	33.8
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		16.5	24.2	31.1
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		15.6	22.9	29.3
Typical Wall Mass (kg/m^2) (with Mortar)	CSA "A" – Type "A" Concrete (2100 kg/m^3)		267	393	504
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		242	356	456
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		223	328	420
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		210	309	396
Minimum Compressive Strength (MPa)	Based on Net Area		15	15	15
	Based on Gross Area		7.9	11.7	15
Fire Resistance Rating (hours)	S or N of NBCC (Normal Weight)	9	2.4	4+	4+
	$L_2$20S of NBCC (Light Weight)		3.5	4+	4+
Sound Properties	Sound Transmission Class (STC)	10	51	56	58
	- CSA Type "A", "B" Concrete		49	54	56
	- CSA Type "C", "D" Concrete				
Thermal Properties (m^2 °C/W)	RSI Factors	11	0.24	N/A	N/A
	- CSA Type "A", "B" Concrete		0.33	N/A	N/A
	- CSA Type "C", "D" Concrete				
Moment of Inertia (mm^4)	Per Block, I		334.9×10^6	437.0×10^6	449.3×10^6
	Per Metre, I_m		858.8×10^6	1131×10^6	1152×10^6
Section Modulus (mm^3)	Per Block, S		2.791×10^6	3.642×10^6	3.744×10^6
	Per Metre, S_m		7.156×10^6	9.338×10^6	9.600×10^6

* Information to be used in conjunction with explanatory notes on Page 4-26

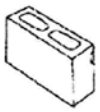
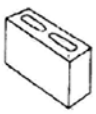
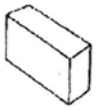

CCMPA METRIC SIZE CODE
25
HOLLOW
Dimensions in mm
B 25
A 25
52
125
125
390
PLAN
190
28
28
28
240
35
35
SECTION A-25
SECTION B-25


CCMPA METRIC SIZE CODE
25
75% SOLID
Dimensions in mm
D 25
C 25
54
82
118
82
390
PLAN
190
30
30
30
30
240
75
75
SECTION C-25
SECTION D-25

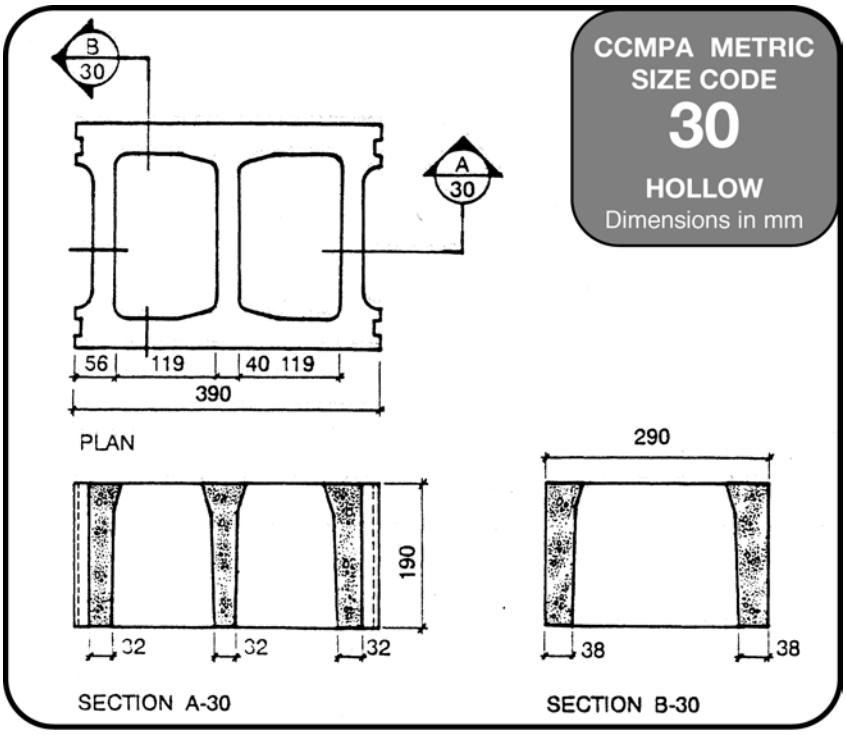
Physical Properties

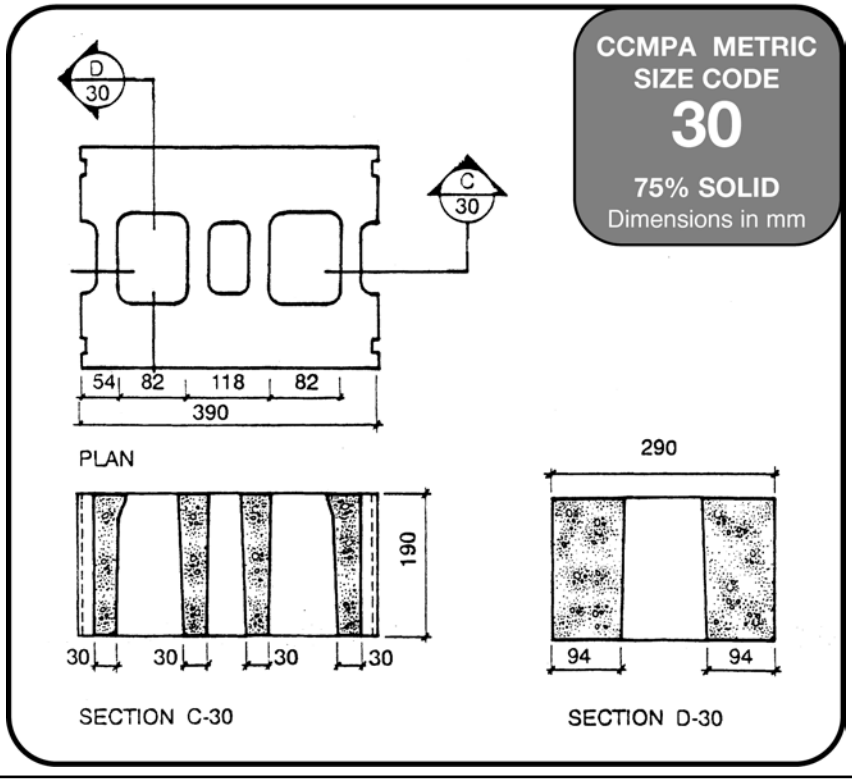
PHYSICAL PROPERTIES OF STANDARD METRIC SIZE BLOCK

SIZE CODE 30

ACTUAL DIMENSIONS (mm) Width 290 Length 390 Height 190		NOTES*	STANDARD CONFIGURATION		
PROPERTIES			HOLLOW	75% SOLID	SOLID
					
Dimensions (mm)	Minimum Faceshell Thickness	1	38	90	N/A
	Minimum Web Thickness	1	32	30	N/A
	Equivalent thickness	2	148	227	290
Area (mm^2)	Gross Cross-sectional Area	3	11.31×10^4	11.31×10^4	11.31×10^4
	Net Cross-sectional Area	4	5.77×10^4	8.82×10^4	11.31×10^4
	Cell (Core) Area	5	2.50×10^4	1.07×10^4	N/A
Volume (mm^3)	Gross Volume	6	21.489×10^6	21.489×10^6	21.489×10^6
	Net Volume	7	10.96×10^6	16.76×10^6	21.489×10^6
Percentage Solid	Net Volume/Gross Volume		51%	78%	100%
Typical Unit Mass (kg)	CSA "A" – Type "A" Concrete (2100 kg/m^3)	8	23	35.2	45.1
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		20.8	31.8	40.8
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		19.2	29.3	37.6
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		18.1	27.7	35.5
Typical Wall Mass (kg/m^2) (with Mortar)	CSA "A" – Type "A" Concrete (2100 kg/m^3)		311	475	609
	CSA "B" – Type "B" Concrete (1900 kg/m^3)		281	430	551
	CSA "C" – Type "C" Concrete (1750 kg/m^3)		259	396	508
	CSA "D" – Type "D" Concrete (1650 kg/m^3)		244	373	479
(Minimum) Specified Compressive Strength (MPa)	Based on Net Area		15	15	15
	Based on Gross Area		7.6	11.7	15
Fire Resistance Rating (hours)	S or N of NBCC (Normal Weight)	9	3.2	4+	4+
	$L_2$20S of NBCC (Light Weight)		4+	4+	4+
Sound Properties	Sound Transmission Class (STC)	10			
	- CSA Type "A", "B" Concrete		53	58	58
	- CSA Type "C", "D" Concrete		50	56	58
Thermal Properties ($m^2 \cdot °C/W$)	RSI Factors	11			
	- CSA Type "A", "B" Concrete		0.26	N/A	N/A
	- CSA Type "C", "D" Concrete		0.41	N/A	N/A
Moment of Inertia (mm^4)	Per Block, I		570.4×10^6	771.0×10^6	792.6×10^6
	Per Metre, I_m		1463×10^6	1977×10^6	2032×10^6
Section Modulus (mm^3)	Per Block, S		3.934×10^6	5.317×10^6	5.466×10^6
	Per Metre, S_m		10.09×10^6	13.63×10^6	14.02×10^6

* Information to be used in conjunction with explanatory notes on Page 4-26


CCMPA METRIC SIZE CODE
30
HOLLOW
Dimensions in mm
B 30
A 30
56 119 40 119
390
PLAN
190
32 32 32
290
38 38
SECTION A-30
SECTION B-30


CCMPA METRIC SIZE CODE
30
75% SOLID
Dimensions in mm
D 30
C 30
54 82 118 82
390
PLAN
190
30 30 30 30
290
94 94
SECTION C-30
SECTION D-30

Explanatory Notes

NUMBER	DESCRIPTION
1	Actual dimensions may exceed minimum requirements.
2	e.g. Calculating Equivalent Thickness: 20 cm Hollow Concrete Block Percentage Solid 56% as per CCMPA specification Equivalent Thickness = Actual Width x Percentage Solid = 190 mm x $\frac{56}{100}$ Equivalent Thickness = 106 mm
3	Stated Gross Cross-sectional Area, defined by the CSA-A165.1, is the area of masonry on a plane parallel to the bearing surface of the unit, determined by multiplying the actual width x actual length of the unit.
4	Stated Net Cross-sectional Area is the net area at mid-height of the unit. For hollow and semi-solid units, this differs slightly from the average net cross-sectional area of the unit.
5	Stated Cell (Core) Area is the total cell area measured at mid-height of the unit.
6	Stated Gross Volume is the product of (actual width) x (actual height) x (actual length) of the unit.
7	Net Volume, as defined by the National Building Code of Canada, NBCC-10, D-1.6.1.(4): "Determined by using a volume displacement method that is not influenced by the porous nature of the unit."
8	Gross Volume, as defined by the National Building Code of Canada, NBCC-10, D-1.6.1.(4): "Determined by using a volume displacement method that is not influenced by the porous nature of the unit."
9	Fire Ratings are based on *"Appendix D—Fire Performance Ratings"* of the National Building Code, NBCC-10. For additional information, refer to Chapter 5 – Fire Performance.
10	Refer to Chapter 7 – Sound Performance, for detailed information.
11	Refer to Chapter 6 – Thermal Performance, for detailed information.