Performance Guidelines for Concrete Masonry Units – Last Revised May 2, 2011

1. Introduction
For nearly a century, the concrete masonry industry in North America has manufactured products to comply with the requirements of ASTM C90, Standard Specification for Loadbearing Concrete Masonry Units, or an equivalent standard (such as ASTM C145 or CSA 165.1). It has long been recognized that meeting all of the requirements of ASTM C90 (physical as well as material) ensures satisfactory performance of the product in service. Meeting all of the requirements of ASTM C90 also inherently demonstrates that such concrete masonry units will exhibit the intrinsic properties that are commonly associated with concrete masonry; such as durability and fire resistance.

As a standard, ASTM C90 is written to apply to the majority of concrete masonry products produced. It cannot, however, apply to all products in all situations as compliance testing would become too expensive and too onerous for commonly produced products with a proven track record. Nevertheless, there may be a legitimate need to deviate from the constituent materials or physical properties defined by ASTM C90 for some applications. In doing so, however, additional evaluation and assessment may be warranted to ensure that the performance of such products meet or exceed performance attributes of the quintessential concrete masonry assembly.

1.1 Use and Application of This Guide
Because of the very broad applications of concrete masonry assemblies (ranging from structural uses in buildings and hardscapes, fire walls and barriers, and energy efficient building enclosures) establishing equivalency with ASTM C90 may not be easy – and may in fact be unfeasible for some exotic materials or unit configurations. This should be noted and referred to when developing an assessment program to demonstrate equivalency with ASTM C90 as it may be more feasible, timely, or cost effective to take a different compliance path – such as may be available through an established evaluation service.
Some unit configurations (or architectural features on the surfaces of units) cannot be manufactured with current technology and may instead be (for example) a wet-cast product. While the method of manufacturing is not specified in ASTM C90, the physical requirements contained in this guide have been developed for, and are applicable to, dry-cast concrete masonry materials. As such, application of the performance requirements and the related test methods or assessment procedures referenced in this guide may or may not be appropriate for other types of concrete products.

This guide outlines industry-recommended assessment and performance criteria that should be taken into consideration when manufacturing concrete masonry units:

1. Using constituent materials other than those explicitly defined by ASTM C90 as outlined in Section 2 of this guide; and

2. That have a configuration that does not meet the prescriptive requirements or dimensions defined by ASTM C90 as outlined in Section 3 of this guide.

While this guide addresses many commonly encountered physical and material topics, it does not address all conceivable questions that can surface when using alternative constituent materials or unit configurations. As new topics or questions are raised, they will be covered with future updates to these guidelines. Users of this guide should have a strong understanding of concrete masonry materials, production techniques, and design requirements to ensure that the assessment procedures used are applicable and meaningful to the product(s) being evaluated and the results of such evaluations are being correctly interpreted.

Commentary – As reflected throughout this document, the assessment and performance criteria of these guidelines are intentionally structured as recommended practices, not mandates. Users of these guidelines should apply sound judgment when selecting and applying these recommendations noting that a specific material or unit configuration may warrant additional or different evaluation techniques. Likewise, one could also reasonably conclude that some of these guidelines would not be applicable or would not provide beneficial information when used to evaluate a specific material or unit configuration. When unsure of the purpose or goal of a specific test or recommended evaluation, users should seek the input of subject matter experts.
1.2 Unit Classification
Meeting all of the requirements (physical as well as material) of ASTM C90 should inherently demonstrate compliance and ensure satisfactory performance of the product in service. For units that do not meet one or more of the defined material or physical requirements or one or more of the aspects of the definition of a concrete masonry unit, the recommendations contained in this guide have been established to consider what additional testing, assessment, or evaluation may be necessary to ensure the product’s performance in service.Demonstrating a product has properties similar to or exceeding those of ASTM C90 does not necessarily make the product a concrete masonry unit in strict accordance with the definition of a concrete masonry unit. Instead, units would be considered either “ASTM C90 Compliant” or “Code-Compliant” according to the following two categories:

1. ASTM C90 Compliant Concrete Masonry Unit – This designation is reserved for concrete masonry units that comply with all explicit requirements for materials and physical properties as defined by ASTM C90, with the exception that other constituent materials permitted by Section 4.3 of ASTM C90 are limited to 1.0% by weight or volume. These units can be used in any application where ASTM C90 compliance is required or permitted by building codes for concrete masonry units.

2. Performance Based Concrete Masonry Unit – This designation applies to concrete masonry units that have demonstrated satisfactory performance as outlined in this guide, but would not otherwise meet all default or prescriptive requirements defined by ASTM C90.

Products that cannot be classified into one of these two categories are not considered to be concrete masonry units and should not claim compliance with ASTM C90 – even if such products meet all the physical property requirements (compressive strength, linear drying shrinkage, dimensions, etc.) of ASTM C90. As this guide emphasizes, there are numerous intrinsic properties associated with concrete masonry construction that are not directly or indirectly evaluated using ASTM C140, Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units, or ASTM C426, Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units; as required by ASTM C90. For such performance assessment and benchmarking, the procedures of this guide are recommended.

In the case where a product does not meet the recommended assessment criteria for an “ASTM C90 Compliant” concrete masonry unit, but does meet the performance requirements of a “Performance Based” concrete masonry unit, limitations may be established for specific applications where equivalency with conventional concrete
masonry units has not been verified. For example, if a product has not demonstrated fire resistance equivalent to a concrete masonry assembly, but has shown equivalent or better performance with all other properties, such a product may still be used in construction provided the resulting assembly is treated and designed as combustible construction (or other appropriate classification) in accordance with the locally adopted building code, provided the other considerations outlined in this guide are taken under consideration. Such products, while not interchangeable with concrete masonry units, may still have value in limited applications.

Commentary – In no case should the content of this guide be construed as permitting the use of a product that would compromise life safety or property protection below that established by the requirements of the governing building code. On the contrary, this guide, in combination with the above unit classifications, is intended to provide a relatively simple, quantifiable means of predicting unit and assembly performance across a broad range of conditions under common exposure and design applications.

2. Constituent Materials
It is recommended that the constituent materials used to manufacture concrete masonry units for compliance with, or equivalency to, ASTM C90 meet the criteria defined in Section 2.1 or 2.2.

2.1 Deemed-to-Comply Criteria – Materials
ASTM C90, Standard Specification for Loadbearing Concrete Masonry Units, defines in Section 4 of that standard the minimum requirements, characteristics, and properties for constituent materials used in the production of concrete masonry units. These requirements include the following:

4.1 Cementitious Materials—Materials shall conform to the following applicable specifications:
   4.1.1 Portland Cement—Specification C150.

   4.1.2 Modified Portland Cement—Portland cement conforming to Specification C150, modified as follows:
   (1) Limestone—If calcium carbonate is added to the cement, the CaCO3 content shall not be less than 85 %.

   (2) Limitation on Insoluble Residue—1.5 %.

   (3) Limitation on Air Content of Mortar—Volume percent, 22 % max.

   (4) Limitation on Loss on Ignition—7 %.
4.1.3 Blended Hydraulic Cements—Specification C595.

4.1.4 Hydraulic Cement—Specification C1157.

4.1.5 Pozzolans—Specification C618.

4.1.6 Blast Furnace Slag Cement—Specification C989.

4.2 Aggregates—Aggregates shall conform to the following specifications, except that grading requirements shall not necessarily apply:

4.2.1 Normal Weight Aggregates—Specification C33.

4.2.2 Lightweight Aggregates—Specification C331.

Commentary – In the context of the above material requirements of ASTM C90, the term “calcium carbonate” in Section 4.1.2(1) is intended to capture and include all limestone materials. The intent of this section is to stipulate a minimum calcium carbonate content of the ground limestone mixed with the cement. Hence, limestone (generically) should contain at least 85% calcium carbonate (CaCO₃) by mass. Further, recent changes to ASTM C150 have reduced the minimum amount of calcium carbonate in limestone from 85% to 70%. This change has not yet been reflected in ASTM C90.

Concrete masonry units manufactured using constituent materials complying with these requirements, and only these constituent materials, are deemed to have satisfied the intrinsic performance characteristics expected of concrete masonry units when placed in service. Verification of the physical properties of concrete masonry units manufactured using these constituent materials is still required in accordance with ASTM C140, Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units, and ASTM C426, Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units.

2.1.1 Material Exemptions

The following materials, when used in accordance with applicable manufacturer’s recommendations or industry practice, have demonstrated a history of successful application and shown to be suitable for use in the production of concrete masonry units. Concrete masonry units containing these materials, or materials limited by weight or volume according to the following, need not be evaluated using Section 2.2 of this guide.

- Pigments meeting the requirements of ASTM C979, Standard Specification for Pigments for Integrally Colored Concrete.

- Silica fume meeting the requirements of ASTM C1240, Standard Specification for Silica Fume Use in Cementitious Mixtures.

- Other constituent materials that have been shown by test or experience not to be detrimental to the durability of the concrete masonry units or any material
customarily used in masonry construction provided that the material is limited to 1.0% by weight or volume of the finished unit.

Commentary – There is no technical reason for ASTM C90 not to reference ASTM C979 or ASTM C1240 for pigments and silica fume, respectively. The lack of reference to these standards is likely an oversight that will be corrected within ASTM C90 in the near future.

2.2 Performance Assessment Criteria – Materials
The list of constituent materials in Sections 4.1 and 4.2 of ASTM C90 represent the materials typically used in concrete masonry units for the past century. Due to their history and use, along with years of research and testing, it is known that when these materials are used and the units meet the other requirements of ASTM C90, the resulting construction will have certain intrinsic properties commonly associated with concrete masonry; such as durability and fire resistance. Nevertheless, the use of materials that do not meet either the definition or the physical requirements of Section 4.1 or 4.2 of ASTM C90 are permitted to be used under Section 4.3 of ASTM C90, which reads as follows:

4.3 Other Constituents—Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, and other constituents shall be previously established as suitable for use in concrete masonry units and shall conform to applicable ASTM standards or shall be shown by test or experience not to be detrimental to the durability of the concrete masonry units or any material customarily used in masonry construction.

Section 2.2 of this guide is intended to provide definitive guidance on the assessment of concrete masonry units manufactured with other constituents, as permitted by Section 4.3 of ASTM C90, when the weight or volume of the other constituent materials exceeds the 1.0% limit permitted by Section 2.1.1 of this guide.

In the discussions and recommendations of this guide, references to “undefined constituent material(s)” means any material intentionally used in the production of a concrete masonry unit that is not explicitly defined under Section 4.1 or 4.2 of ASTM C90 or otherwise exempted under Section 2.1.1 of this guide.

Commentary – As discussed in Section 1.1, it would be impossible for this guide to address all known (as well as yet-to-be-identified) constituent materials that could conceivably be used in the production of concrete masonry products. Rather, this guide is intended to capture commonly encountered materials and questions and provide the user with assessment recommendations accordingly.

The source of materials, particularly waste and by-product materials, should be well documented to avoid the inadvertent introduction of toxic or hazardous materials into a concrete masonry unit. When the source of a material is unknown, or when the presence of a toxic substance is reasonably suspected, the material should be evaluated using a
TCLP test (Toxicity Characteristic Leaching Procedure). The TCLP test analyzes the leachate for the presence of hazardous, corrosive, reactive, and similar toxic substances. Any material that exceeds the maximum concentration of contaminants for toxicity as set by the U.S. Environmental Protection Agency should not be used in the production of concrete masonry units.

Section 2.2 of this guide does not include assessment or performance guidelines for cementitious materials that could be used in the production of concrete masonry units. ASTM C90 currently permits the use of cement meeting the requirements of ASTM C1157, Standard Performance Specification for Hydraulic Cement. As a performance specification, ASTM C1157 does not place restrictions or limitations on the composition or constituent materials of the cement; rather ASTM C1157 establishes minimum performance requirements for cementitious materials. As such, ASTM C1157 already provides considerable flexibility in evaluating alternative cementitious materials that does not need to be repeated in this guide.

2.2.1 Glass Aggregate Materials
In addition to the requirements of ASTM C90, the following evaluations should be considered for concrete masonry units containing glass aggregate:

- Fire Resistance – If the concrete masonry unit is to be used in a fire rated assembly, the fire resistance rating should be determined in accordance with Appendix A of this guide.

- Alkali-Silica Reaction – The potential alkali-silica reactivity should be evaluated in accordance with Appendix B of this guide.

- Thermal Properties – If the concrete masonry unit is to be incorporated into the thermal envelope of a building, the thermal resistance/transmittance properties of the unit should be determined in accordance with Appendix C of this guide.

Commentary – A common source of glass cullet used as an aggregate in the production of concrete masonry units is through municipal recycling centers. Such sources present unique challenges to ensure that the recycled glass is clean (free of residual sugars that may impede the hydration of cement) and free of debris (such as wrappers and bottle labels). The guidelines of Section 2.2.1 assume that the glass aggregate is clean and free of debris that would otherwise interfere with the production of a unit or its permanence in service. Glass cullet consisting of plate glass should be avoided.

2.2.2 Cellulosic Materials
In addition to the requirements of ASTM C90, the following evaluations should be considered for concrete masonry units containing cellulosic materials:

- Fire Resistance – If the concrete masonry unit is to be used in a fire rated assembly, the fire resistance rating should be determined in accordance with Appendix A of this guide.
Thermal Properties – If the concrete masonry unit is to be incorporated into the thermal envelope of a building, the thermal resistance/transmittance properties of the unit should be determined in accordance with Appendix C of this guide.

Decay Resistance – The decay resistance should be evaluated in accordance with Appendix D of this guide.

Termite Resistance – The termite resistance should be evaluated in accordance with Appendix E of this guide.

Mold Resistance – The mold resistance should be evaluated in accordance with Appendix G of this guide.

Commentary – Most cellulosic-based materials will undergo extreme volume changes when exposed to moisture, which may make them unsuitable for use in the production of concrete masonry units. The impact of a constituent material on the dimensional stability of a concrete masonry unit is assessed using ASTM C426. All units, regardless of their constituent materials or configuration, must still comply with the maximum linear drying shrinkage of ASTM C90.

2.2.3 Aggregate Derived from Crushed Concrete
In addition to the requirements of ASTM C90, the following evaluations should be considered for concrete masonry units containing crushed concrete:

- Fire Resistance – If the concrete masonry unit is to be used in a fire rated assembly, the fire resistance rating should be determined in accordance with Appendix A of this guide.

- Alkali-Silica Reaction – The potential alkali-silica reactivity should be evaluated in accordance with Appendix B of this guide.

- Thermal Properties – If the concrete masonry unit is to be incorporated into the thermal envelope of a building, the thermal resistance/transmittance properties of the unit should be determined in accordance with Appendix C of this guide.

- Freeze-Thaw Durability – If the concrete masonry unit is to be used in areas where repeated freezing and thawing under saturated conditions occur, freeze-thaw durability should be evaluated in accordance with Appendix F.

Commentary – ASTM C33 explicitly covers the use of crushed concrete as a source aggregate. If the crushed concrete meets the requirements of ASTM C33, then additional testing or assessment in accordance with the recommendations of this guide may not be necessary as discussed in Section 1 of this guide. Note that ASTM C90 permits the
gradation requirements of ASTM C33 to be waived. ASTM C33 also includes the following note that should be taken into consideration when using crushed concrete aggregates:

NOTE 6—Although crushed hydraulic-cement concrete has been used as an aggregate with reported satisfactory results, its use may require some additional precautions. Mixing water requirements may be increased because of the harshness of the aggregate. Partially deteriorated concrete, used as aggregate, may reduce freeze-thaw resistance, affect air void properties or degrade during handling, mixing, or placing. Crushed concrete may have constituents that would be susceptible to alkali-aggregate reactivity or sulfate attack in the new concrete or may bring sulfates, chlorides, or organic material to the new concrete in its pore structure.

In the context of Section 2.2.3, crushed concrete includes any concrete material from dry-cast or wet-cast sources, including cast-in-place, precast, and manufactured concrete. The source of the crushed concrete should be documented to prevent the unintentional introduction of contaminants and deleterious materials.

2.2.4 Fine Grained Soils
In addition to the requirements of ASTM C90, the following evaluations should be considered for concrete masonry units containing fine grained soils as defined by the Unified Soil Classification System (USCS):

- Fire Resistance – If the concrete masonry unit is to be used in a fire rated assembly, the fire resistance rating should be determined in accordance with Appendix A of this guide.

- Thermal Properties – If the concrete masonry unit is to be incorporated into the thermal envelope of a building, the thermal resistance/transmittance properties of the unit should be determined in accordance with Appendix C of this guide.

- Termite Resistance – The termite resistance should be evaluated in accordance with Appendix E of this guide.

- Freeze-Thaw Durability – If the concrete masonry unit is to be used in areas where repeated freezing and thawing under saturated conditions occur, freeze-thaw durability should be evaluated in accordance with Appendix F.

Commentary – The Unified Soil Classification System defines fine grained soils as soils where more than half of the material is smaller than a No. 200 sieve. This includes silt and clay materials with low to high plasticity. Organic soils are not appropriate for use in the production of concrete masonry units.

2.2.5 Plastic Aggregate Materials
In addition to the requirements of ASTM C90, the following evaluations should be considered for concrete masonry units containing plastic aggregate:
• Fire Resistance – If the concrete masonry unit is to be used in a fire rated assembly, the fire resistance rating should be determined in accordance with Appendix A of this guide.

• Thermal Properties – If the concrete masonry unit is to be incorporated into the thermal envelope of a building, the thermal resistance/transmittance properties of the unit should be determined in accordance with Appendix C of this guide.

• Termite Resistance – The termite resistance should be evaluated in accordance with Appendix E of this guide.

• Freeze-Thaw Durability – If the concrete masonry unit is to be used in areas where repeated freezing and thawing under saturated conditions occur, freeze-thaw durability should be evaluated in accordance with Appendix F.

• UV Resistance – The resistance to ultraviolet light should be evaluated in accordance with Appendix H of this guide.

2.2.6 Other Materials
Other constituent materials not otherwise covered in Section 2.2 of this guide may be suitable for use in the production of concrete masonry units provided that the performance of the units containing the undefined constituent material is understood and documented for the anticipated exposure conditions of the assembly in which the unit is to be used.

Commentary – This guide is not intended to explicitly address all conceivable materials that could be used in the production of concrete masonry units with satisfactory results. The absence of a material from this guide should not be construed as a prohibition of such a material.

3. Unit Configuration
One of the great features of concrete masonry construction is the inherent flexibility of the system afforded through varying the configuration of the individual units. The configuration of units can be altered to achieve desired aesthetic effects, structural capabilities, construction productivity, energy efficiency, or any number of other intrinsic properties inherent to concrete masonry construction.

The creativity and imagination of the marketplace in designing and developing novel unit configuration far exceeds the ability of prescriptive national standards to keep pace. Case in point, the requirements of ASTM C90 and the companion testing standard ASTM C140 are by necessity generic in nature – applying to the majority, but not all, configurations of units. As special or proprietary units are introduced to the market, they may not be able to be evaluated consistently or accurately under ASTM C140, or may not have all of the relevant features to demonstrate compliance with ASTM C90 by default without supplemental evaluation.
It is recommended that concrete masonry units meet the unit configuration requirements of Section 3.1 or 3.2.

3.1 Deemed-to-Comply Criteria – Unit Configuration
Units that meet the minimum face shell and web thickness requirements defined in ASTM C90, including the equivalent web thickness requirements, or are solidly grouted following installation are considered to have satisfied the intrinsic performance attributes based solely on unit configuration for concrete masonry units.

3.2 Performance Assessment Criteria – Unit Configuration

3.2.1 Alternative Web Thickness or Web Height
To increase the energy efficiency of a unit, to accommodate varying reinforcement schedules, increase construction productivity, or any number of other reasons, the webs of a concrete masonry unit may be reduced or altered to achieve a desired property. Because webs can be altered in a near unlimited number of ways and degrees, ASTM C140 does not contain a standardized method of assessing the performance of a unit that uses an alternative web configuration.

Units that are manufactured with a web thickness or equivalent web thickness that does not meet the minimum requirements of ASTM C90 should be evaluated using the criteria outlined in Section 3.2.1.1. Likewise, units that are manufactured with webs that are less than 75% of the specified height of the unit at any location should be evaluated using these same criteria. Units that are intended to be solidly grouted are exempt from these criteria and are deemed-to-comply with the web requirements of ASTM C90.

The purpose of the minimum equivalent web thickness requirements in ASTM C90 is to ensure that sufficient material is provided between the two face shells of a unit to transfer stresses from one face shell to the other so that the unit acts as a composite structural assembly. While not explicitly stated within ASTM C90, this standard does in effect define a de facto minimum connection strength between two face shells by:

1. defining a minimum equivalent web thickness; and

2. defining a minimum unit compressive strength.

In cases where the configuration of a concrete masonry unit or its webs does not comply with the requirements of ASTM C90, or cannot be tested or evaluated using the procedures of ASTM C140, the practices defined in Section 3.2.1.1 are recommended to evaluate the impact of the reduced web configuration. Units having reduced webs that are evaluated in accordance with Section 3.2.1.1 should meet one of the performance criteria defined in Section 3.2.1.2.

3.2.1.1 Reduced Web Assessment Criteria
Shear transfer between the face shells of a unit can be provided by alternative means. One commonly used option is to grout all or portions of a masonry unit, thereby providing more material to transfer stresses between the face shells. Similar technologies can be used as
well that provide equivalent structural performance. When the strength of the material used to transfer stresses between the face shells is known and the configuration of the unit can be reasonably modeled analytically, then the following expression can be used:

\[ \frac{f_v \cdot lb}{Q} \geq V_x \]

Where:
- \( f_v \) = shear strength of the connection material between the face shells, psi
- \( Q \) = first moment of inertia, in.\(^3\)
- \( I \) = moment of inertia, in.\(^4\)
- \( b \) = width at critical shear section, in.
- \( V_x \) = allowable shear load on the unit, lb

For 6 in. and smaller units, \( V_x = 214 \text{ lb/ft} \)
For 8 in. units, \( V_x = 292 \text{ lb/ft} \)
For 10 in. and larger units, \( V_x = 414 \text{ lb/ft} \)

The values for \( V_x \) for the units above are based on being capable of transferring approximately 22 psi, which is approximately one-half of the shear strength determined as follows:

\[ f_v = \sqrt{\text{compressive strength of unit}} = \sqrt{1,900 \text{ psi}} = 43 \text{ psi} \]

3.2.1.2 Reduced Web Performance Criteria
Units not complying with the prescriptive equivalent web thickness requirements of ASTM C90 can be used provided that one of the following conditions is met:

1. Unit are to be solidly grouted in the final construction;

2. Equivalency is demonstrated using the procedures outlined in Section 3.2.1.1 whereby the web connection strength between the face shells of a unit provide the same, or greater, strength as standard C90 units complying with the minimum equivalent web thickness; or

3. The designer when using units that do not comply with the prescriptive minimum equivalent web thickness requirements takes this into consideration when designing and proportioning a structure for the anticipated loads, and resulting forces based on modeled configuration and support conditions.
3.2.2 Alternative Face Shell Configuration

In some instances, it may be desirable to alter the exposed face(s) of a concrete masonry unit for sound abatement, energy efficiency, or to affect some other physical or serviceability attribute of the unit once placed in service. While many of these unit configurations have been used successfully for years, current standards are silent on how to address the evaluation of the properties of such units either individually or as part of an assembly.

For the purposes of these guidelines, the following terms and definitions are used:

- **Webs** – the portion(s) of the unit that structurally connects the face shells. Typically the webs of the unit are not exposed once the unit is installed, except an end-web may be exposed at the corner of a wall.

- **Face shells** – the front and back portions of the unit that can be exposed once the unit is installed.

- **Cross-webs** – the portion(s) of a unit that run parallel to the face shells, connecting one or more webs.

3.2.2.1 Alternative Face Shell Configuration Assessment Criteria

When a unit employs an alternative face shell configuration, the following evaluations, in addition to those required by ASTM C90, should be considered:

- **Fire Resistance** – If the concrete masonry unit is to be used in a fire rated assembly, the fire resistance rating should be determined in accordance with Appendix A of this guide.

- **Thermal Properties** – If the concrete masonry unit is to be incorporated into the thermal envelope of a building, the thermal resistance/transmittance properties of the unit should be determined in accordance with Appendix C of this guide.

- The completed wall assembly should be evaluated in accordance with the soft body impact assessment method in accordance with ASTM C1629/C1629M, *Standard Classification for Abuse-Resistance Nondecorated Interior Gypsum Panel Products and Fiber-Reinforcement Cement Panels*.

- The face shells of the unit should be evaluated in accordance with the hard body impact assessment method in accordance with ASTM C1629/C1629M, *Standard Classification for Abuse-Resistance Nondecorated Interior Gypsum Panel Products and Fiber-Reinforcement Cement Panels*.

- The structural strength and resilience should be evaluated in accordance with ICC-ES AC15, *Acceptance Criteria for Concrete Floor, Roof, and Wall Systems and Concrete Masonry Wall Systems*.

3.2.2.2 Alternative Face Shell Configuration Performance Criteria
The completed wall assembly should meet or exceed the soft body impact classification Level 2 as determined in accordance with ASTM C1629/C1629M, *Standard Classification for Abuse-Resistance Nondecorated Interior Gypsum Panel Products and Fiber-Reinforcement Cement Panels*.

The face shells of the unit should meet or exceed the hard body impact classification Level 3 as determined in accordance with ASTM C1629/C1629M, *Standard Classification for Abuse-Resistance Nondecorated Interior Gypsum Panel Products and Fiber-Reinforcement Cement Panels*.

**Appendix A – Fire Resistance**

A.1 Introduction

One of the most attractive aspects of concrete masonry construction is its inherent non-combustibility and ability to provide effective compartmentation. The International Building Code (IBC) outlines multiple options for documenting the fire resistance rating of concrete masonry assemblies, including:

- Third party listing services, such as Underwriters Laboratory;
- Full-scale testing in accordance with ASTM E119 or equivalent test standard;
- Standardized calculation procedures, such as ACI 216.1/TMS 0216; and
- Alternative means approved by the building official.

Of these alternatives, the calculation procedure using ACI 216.1/TMS 0216, *Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies*, is the most commonly used method of determining fire resistance ratings of concrete masonry assemblies. This calculation is based on the equivalent thickness of the unit and the aggregates used during unit production. Based upon the calculation procedures defined in ACI 216.1/TMS 0216, the fire resistance rating of a broad range of mix designs and unit configurations can be determined, alleviating the need and expense associated with testing each unique unit configuration and mix design for fire resistance.

The limitation of the calculation approach is that only eleven common aggregates are explicitly addressed in the standard. When an aggregate (or other constituent material) is used in the production of a concrete masonry unit that is not addressed by ACI 216.1/TMS 0216, or if the unit’s configuration is significantly unique such that it cannot be reasonably modeled using the calculation procedure, a simple calculation to determine the fire resistance rating of the assembly may not be possible – or at the very least may only approximate the fire resistance rating of the assembly. In such cases, it may be necessary to conduct testing in accordance with ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, to determine the fire resistance rating as well as document the performance of the unit under elevated temperatures.
While test methods such as ASTM E119 define procedures for evaluating the fire resistance properties of concrete masonry assemblies, including those constructed using unconventional constituent materials, there has historically been no defined procedure for extrapolating the results of testing to different mix designs or unit configurations. In theory, this could necessitate the testing of a nearly infinite number of specimens to cover the range of mix designs and unit configurations commonly used in construction. To provide consistency in applying the results of full-scale ASTM E119 testing to established calculation procedures, the guidelines and recommendations outlined in this Appendix should be followed.

This guideline recommends testing at least two full-scale assemblies in accordance with ASTM E119. Based on the results of the full-scale testing, an expression is developed in accordance with this industry practice that permits the fire resistance rating of units manufactured with constituent materials not defined by ASTM C90 for interpolated values of equivalent thickness and proportion of undefined constituent material.

In reviewing the various testing and modeling options available in an attempt to capture each of the physical attributes directly or indirectly evaluated through full-scale ASTM E119 testing, the following performance criteria were considered in the development of the guidelines outlined in this Appendix:

- Heat transfer characteristics through an assembly;
- Flame spread and combustibility;
- Smoke release and generation;
- Material degradation;
- Loss of structural strength at elevated temperatures;
- Excessive expansion of materials at elevated temperatures;
- Resistance to impact from hose stream application; and
- Resistance to thermal shock during hose stream application.

Although many of these attributes can be evaluated independently through either physical testing or computer modeling, in many cases, the expense and resources needed to comprehensively consider each performance characteristic would greatly exceed the cost of conducting a few full-scale ASTM E119 tests. Further, the results obtained through independent evaluation of each performance attribute would likely be less definitive, and less widely accepted, relative to ASTM E119 testing.

Given the above discussion, the subsequent conclusion is that full-scale ASTM E119 testing would be necessary to quantify the performance of concrete masonry units produced using constituent materials that are not explicitly defined by ASTM C90. In order to reasonably
interpolate between test points, at least two full-scale ASTM E119 test specimens are recommended.

A.2 Assessment Guidelines

Conduct two full-scale ASTM E119 tests on assemblies constructed using units manufactured with the undefined constituent materials. If the assemblies are intended for loadbearing application, the loadbearing testing procedures of ASTM E119 should be followed.

Ideally, each test would be performed on units manufactured using the largest percentage of the undefined constituent material that would be expected to be used and having two extremes in equivalent thickness. Blending of defined and undefined constituent materials is permitted; however, extrapolation of a fire resistance rating using higher percentages of an undefined constituent material should not be done. Likewise, application of the calculated fire resistance method to equivalent thicknesses less than or greater than those tested in accordance with ASTM E119 may not be justifiable.

A.3 Performance Guidelines

Testing in accordance with ASTM E119 yields a fire resistance rating rather than a pass/fail result. As such, the performance of concrete masonry assemblies containing undefined constituent materials and evaluated using ASTM E119 produces an hourly rating that may be less than, greater than, or the same as similarly configured concrete masonry units manufactured with defined constituent materials.

Based upon the results of the ASTM E119 testing, the fire resistance rating can be interpolated between the two data points obtained through testing. There are, however, limitations when applying these guidelines, which include:

- The results of the calculated fire resistance rating could not be applied to units having a smaller or larger equivalent thickness than those used in the full-scale ASTM E119 testing. Given the nonlinear and dynamic nature of heat transfer through concrete masonry assemblies, it would not be clear as to whether such extrapolations would be conservative or unconservative. It would, however, be acceptable to solidly fill hollow units produced with undefined constituent materials with approved materials (such as grout) or apply approved finishes to the assembly to increase the fire resistance rating.

- The results of the calculated fire resistance rating could not be applied to units manufactured with a larger percentage of the undefined constituent material than that tested during ASTM E119 evaluation. Ideally, a mix design containing the largest percentage of the undefined constituent material would be tested in accordance with ASTM E119. If this isn’t practical, however, the results of the ASTM E119 testing should not be extrapolated to mix designs containing larger percentages of the undefined constituent material. Mix designs containing a smaller percentage of the undefined constituent material would be acceptable.
• Combining two or more types of undefined constituent materials would not be permitted unless each is independently evaluated under ASTM E119.

• Units evaluated would need to comply with the minimum physical requirements per ASTM C90 to help ensure that the results of the fire resistance testing are appropriately applied to units that would qualify for use in actual construction.

• The mode of failure of the assembly tested per ASTM E119 containing the undefined constituent material would need to be the same as the mode of failure for assemblies constructed with units manufactured with defined constituent material. Concrete masonry assemblies tend to fail as a result of temperature increase on the non-exposed side of the test assembly.

• Mathematically, there may be different ways of interpolating calculated values using different “weighting factors”. Although the difference is likely insignificant, for consistency in application, the lowest (most conservative) calculated fire resistance rating should be used when interpolating results.

Appendix B – Alkali-Silica Reaction

B.1 Introduction
There are numerous tests and procedures for assessing potential alkali reactivity of materials incorporated into cementitious products, partly driven by the fact that there is no general consensus on correlating the results of the testing to expected performance in service. As such, the selection of the appropriate test method, and the interpretation of the results of such testing, should be cautiously.

While alkali reactions have historically been predominately a problem with wet-cast concrete products relative to dry-cast concrete products, there is nevertheless a potential for deleterious alkali-silica reactions to occur in any cementitious product. The recommendations of this Appendix point the user to Appendix X1 of ASTM C33 for assessing potential alkali-silica reaction. This should not be construed as suggesting that all the testing and evaluation techniques discussed in Appendix X1 of ASTM C33 should be conducted, rather, the user should select the appropriate evaluation technique(s) based upon judgment taking into consideration the properties of the undefined constituent material, the anticipated exposure conditions in service, and the historical use of the undefined constituent material, if available.

B.2 Assessment Guidelines
Potential alkali-silica reactivity of undefined constituent materials should be evaluated in accordance with Appendix X1, *Methods for Evaluating Potential for Deleterious Expansion Due to Alkali Reactivity of an Aggregate*, contained in ASTM C33, *Standard Specification for Concrete Aggregates*. 

[NCMA Logo]
Commentary – Appendix XI of ASTM C33 contains multiple options and test methods for assessing potential alkali-silica reactivity of a constituent material; each with potential advantages and disadvantages. Some tests may be more or less prone to false positive results, depending upon the material being evaluated. In addition, the particle size of the aggregate being evaluated can influence the results, with smaller particle sizes tending to exhibit less expansion.

B.3 Performance Guidelines
The potential alkali-silica reactivity of the undefined constituent material should not exceed the recommended limits contained in Appendix XI, Methods for Evaluating Potential for Deleterious Expansion Due to Alkali Reactivity of an Aggregate, of ASTM C33, Standard Specification for Concrete Aggregates.

Appendix C – Thermal Resistance/Transmittance

C.1 Introduction
The thermal performance of concrete masonry assemblies is primarily driven by the thermal mass (thermal inertia) of the product and the configuration of the unit, which influences the thermal bridging across the unit.

Contemporary building codes and standards set minimum energy efficiency requirements for a building’s thermal envelope based upon local climate, project orientation, and building use; which in turn are based upon steady-state U-factors and R-values for a given assembly. While steady-state thermal performance properties neglect the direct contribution of thermal mass, these effects are indirectly taken into consideration through building codes by requiring lower R-values in buildings that incorporate mass walls into the thermal envelope. In order for an assembly to be considered a mass wall building codes require that the installed weight of an assembly be no less than 35 lb/ft to take advantage of the mass wall provisions for energy efficiency. While the majority of concrete masonry assemblies exceed this criterion for installed weight, significant changes to the constituent materials used to manufacture the unit may yield unit densities below this threshold.

This Appendix outlines two alternatives to determining the thermal performance of concrete masonry units being evaluated using these guidelines: calculation and testing. Depending upon the constituent materials used in manufacturing a unit and the unique properties of a unit’s configuration, both method of evaluation may be necessary.

C.2 Assessment Guidelines
Where the thermal resistivity of each of the constituent materials used in manufacturing a concrete masonry unit, or will be integrated into a unit prior to installation, is known, U-factors/R-values can be determined by calculation using the series-parallel method defined by the 2009 ASHRAE Handbook – Fundamentals.
Where the thermal resistivity of each of the constituent materials used in manufacturing a concrete masonry unit, or will be integrated into a unit prior to installation, is not known, U-factors/R-values can be determined by testing in accordance with ASTM C1363, *Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*, or equivalent.

C.3 Performance Guidelines
Evaluation for thermal properties results in a steady-state R-value for a given unit type and configuration rather than a pass/fail criterion. The resulting thermal properties may be less than, greater than, or the same as conventional concrete masonry units. In application, the resulting thermal properties of the unit evaluated using these guidelines would be required to meet the minimum thermal properties stipulated for each specific project in which such units are used.

**Appendix D – Decay Resistance**

D.1 Introduction
The inherent decay resistance of concrete masonry construction permits its use in nearly unlimited applications without concern over the long-term performance of the material in environments that encourage or facilitate decay in other construction materials. Incorporating an undefined constituent material that is susceptible to decay can potentially compromise the performance of the assembly, potentially leading to serviceability or structural problems in service.

The recommended assessment guidelines of this Appendix should be taken into consideration even if the undefined constituent material is fully encapsulated within the unit or completed coated with cement paste in the finished product.

These guidelines compare the relative decay resistance of the concrete masonry unit under evaluation to wood materials that are known to resist deterioration due to decay; specifically redwood, cedar, black locust, and black walnut. These woods are defined by the 2009 International Building Code as being ‘decay resistant’.

D.2 Assessment Guidelines
When a concrete masonry unit incorporates an undefined constituent material that is prone to decay as a result of fungal or bacterial attack, the susceptibility of the unit to premature decay should be assessed in accordance with ASTM D2017-05, *Standard Test Method of Accelerated Laboratory Test of Natural Decay Resistance of Woods*, or equivalent.

D.3 Performance Guidelines
The procedures of ASTM D2017 outline a method of evaluating the relative decay resistance between two or more materials. This test method does not result in a quantifiable rating of decay resistance, for which standardized testing procedures do not currently exist for construction materials.
The relative decay resistance of a concrete masonry unit incorporating an undefined constituent material being evaluated under this Appendix should be better than or equal to the decay resistance of redwood, cedar, black locust, or black walnut wood species evaluated using ASTM D2017.

Where the *International Building Code* places limitations on the use or application of redwood, cedar, black locust, or black walnut materials, those same limitations should also be applied to concrete masonry assemblies incorporating undefined constituent materials being evaluated using this Appendix.

**Appendix E – Termite Resistance**

E.1 Introduction
In regions prone to subterranean termite infestation, the *International Building Code* stipulates limits on materials that can be placed in contact with or near the ground. In the context of these guidelines, termite resistance evaluates not only the susceptibility of a material to be consumed by termites, but also the ability of the material being evaluated to act as a termite barrier. As such, the recommended assessment guidelines of this Appendix should be taken into consideration even if the undefined constituent material is fully encapsulated within the unit or completed coated with cement paste in the finished product.

These guidelines compare the relative termite resistance of the concrete masonry unit under evaluation to wood materials that are known to resist termite infestation; specifically redwood, Alaska yellow-cedar, Eastern red cedar, and Western red cedar. These woods are defined by the 2009 *International Building Code* as being ‘termite resistant’.

E.2 Assessment Guidelines
When a concrete masonry unit incorporates an undefined constituent material that is prone to damage from termites, the susceptibility of the unit to resist termite damage should be assessed in accordance with ASTM D3345, *Standard Test Method for Laboratory Evaluation of Wood and Other Cellulosic Materials for Resistance to Termites*, or equivalent.

Exception: If the product under evaluation is to be used solely in areas where the probability of termite infestation is none to slight, as defined by the *International Building Code*, the risk of termite damage is considered to be sufficiently small and the assessment recommendations of this Appendix need not be conducted.

E.3 Performance Guidelines
The performance of the product under evaluation should demonstrate termite resistance equal to or better than the relative termite resistance of redwood, Alaska yellow-cedar, Eastern red cedar, or Western red cedar when evaluated using ASTM D3345.

Where the *International Building Code* places limitations on the use or application of redwood, Alaska yellow-cedar, Eastern red cedar, or Western red cedar materials, those
same limitations should also be applied to concrete masonry assemblies incorporating undefined constituent materials being evaluated using this Appendix.

Appendix F – Freeze-Thaw Durability

F.1 Introduction
The need to assess unit durability through laboratory freeze-thaw testing depends upon exposure conditions, whether the units are expected to be saturated under repeated freezing and thawing cycles, and whether the units are expected to be exposed to de-icing salts in service. The map below can be used as guidance for determining if freeze-thaw testing is necessary. Units to be placed in service in the region designated Zone 3 should have freeze-thaw testing conducted using the procedures of this Appendix. Conversely, units to be placed in service in the region designated Zone 1 are unlikely to be exposed to deteriorating freeze-thaw conditions. Zone 2 areas should consider the need to freeze-thaw testing; particularly in applications were the units are expected to be exposed to de-icing salts.

F.2 Assessment Guidelines
Products manufactured with undefined constituent materials that are used in areas where repeated freezing and thawing under saturated conditions occur, freeze-thaw durability should be evaluated in accordance with the water evaluation procedures of ASTM C1262, Standard Test Method for Evaluating the Freeze-Thaw Durability of Dry-Cast Segmental Retaining Wall Units and Related Concrete Units, or equivalent.
F.3 Performance Guidelines
Specimens should meet either of the following performance criteria:

1. The weight loss of each of the five test specimens at the conclusion of 20 cycles should not exceed 1% of its initial weight; or

2. The weight loss of each of four of the five test specimens at the conclusion of 30 cycles should not exceed 1.5% of its initial weight.

Appendix G – Mold Resistance

G.1 Introduction
The potential for a substrate to mold during service can result in a number of potential serviceability and performance problems. Additional information on mold and mildew resistance of concrete masonry products is available through NCMA’s TEK series.

G.2 Assessment Guidelines
Products manufactured with undefined constituent materials that may support or encourage the growth of mold or mildew should be evaluated in accordance with ASTM D3273, *Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber*, or equivalent.

G.3 Performance Guidelines
The product being evaluated should not show mold growth with tested in accordance with ASTM D3274, *Standard Test Method for Evaluating Degree of Surface Disfigurement of Paint Films by Fungal or Algal Growth, or Soil and Dirt Accumulation*, or equivalent.

Appendix H – UV Resistance

H.1 Introduction
Some materials degrade when exposed to UV light, most notably some untreated plastics.

H.2 Assessment Guidelines
Products manufactured with undefined constituent materials that may degrade when exposed to ultraviolet light should be evaluated in accordance with ASTM G154, *Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials*, or equivalent.

H.3 Performance Guidelines
The performance of materials evaluated under this Appendix should meet or exceed the minimum weatherability criteria defined in ASTM F964, *Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Exterior Profiles Used for Fending and Railing*, or equivalent.
Appendix I – Accelerated Weathering

I.1 Assessment Guidelines
There are numerous standardized tests for evaluating the weatherability of construction materials that can be used for assessing the durability of a given material used in the production of concrete masonry units. As a relative simply and inexpensive means of conducting ‘weathering’ testing in-house, a sample of units can be left in the curing kiln for an extended period of time to assess their performance on both the aesthetic and physical properties of the units.

I.2 Performance Guidelines
The units should not show degradation or loss of strength after continuous kiln exposure for a period of 4 weeks, or similar exposure conditions.