Introduction
This ARRISCRAFT•NOTE discusses the properties of the calcium silicate masonry units (CSMU), including the applicable reference standards, physical characteristics, freeze-thaw durability and cyclic volumetric changes. CSMU are distinct from both clay bricks and concrete masonry products. Thus it is important that designers develop an understanding of these aspects as they relate to the design of a building.

Basic Description
Calcium silicate masonry units are a manufactured masonry product. Lime and silica-based sand are mixed and then pressed into modular-sized units under high pressure. The "green" units are then subjected to high-pressure steam in an autoclave to produce a masonry unit with uniformly fine-grained texture. A calcium silicate hydrate binder is formed when the elements in the raw materials chemically react in the autoclave. This results in a durable, strong and integrally bonded unit. This process distinguishes calcium silicate units from cement-based masonry units.

Production techniques utilizing high pressure and stringent quality control mean that no significant change in the shape or size of the units occurs when the units are cured. Thus, both the strength and the critical dimensions of the calcium silicate masonry units are extremely uniform.

A wide variety of distinctive colours can be produced, many of which cannot be matched by other types of masonry units. These range from natural white to pastel shades to earthen tones. Proprietary colour blending techniques make it possible to produce striations and ranges similar to those in natural stone.

Calcium silicate masonry units can be cut, shaped, hand-chiseled or dressed while maintaining a fine-grained texture and through-body colour. Calcium silicate masonry units mature in appearance under exposure to normal atmospheric conditions in a manner similar to many natural stones, such as limestone.

Calcium silicate masonry units provide building designers with the opportunity to use a material of controlled high strength with natural appearance and well-established durability at an economical cost.

Applicable Standards
In North America calcium silicate products are described by ASTM C73-99a, *Standard Specification for Calcium Silicate Face Brick*. This standard specifies the requirements for compressive strength and absorption in order for the material to be classified as either moderate- or severe-weathering.

It is important to realize that calcium silicate masonry units are distinct from cement-based products and, therefore, product standards specific to cement-based materials do not apply.

Within the calcium silicate standards there are no performance requirements with respect to freeze-thaw durability. It is generally accepted that the durability of calcium silicate masonry is closely related to its strength properties. Freeze-thaw performance is thus controlled by the strength requirements in the standard. Further discussion on performance testing for freeze-thaw durability follows.

Arriscraft calcium silicate products meet the "severe-weathering" requirements of the C73 standard.

Quality Assurance Program
The quality assurance program of any masonry product manufacturer must ensure that their products meet the requirements of the standards by means of a proven sampling and testing program. An internal program must ensure that product sampling adequately represents the production and that action limits are set to minimize the chances that any unacceptable product may reach the job site.

Calcium silicate products are typically sampled and tested on a lot-by-lot basis. All sampled products are tested for hardness. This property can be correlated to the compressive strength of the material. Select samples from each production line are then subjected to intensive testing for compressive strength, absorption, density and freeze-thaw durability. Pre-screening of aesthetic properties such as colour and colour distribution are also performed on all sampled material so that production personnel can be alerted to any possible concerns. The production process is configured to allow for 100% inspection of the product for conformance to the aesthetic criteria discussed below.

Physical Properties
Compressive strength is the ultimate crushing load at which a material will commence to fail by fracturing. This property has been used as a measure of quality and as a means of prediction of other properties. Note that tested or apparent compressive strengths will vary with the size and the shape of the specimen tested mainly

due to constraint on the contact area between the specimen and the loading platens of the testing machine. Therefore, when comparing compressive strength values, the possible effects of varying specimen size and shape must be considered.

Modulus of rupture is a measure of resistance to bending action or flexural strength, and in the case of calcium silicate masonry units, can also be used as a measure of the resistance to cracking of individual units due to internal bending stresses set up within the wall.

Absorption is the ratio expressed as a percentage of the weight of water absorbed by the specimen when soaked in cold water for 24 hours compared to the original dry weight. Alternatively, the 24-hour absorption can be expressed as a ratio of the weight of water absorbed per unit volume of masonry material. Limits may be established for different types of material to minimize the potential for freeze-thaw damage, excessive volumetric change or excessive permeability to water penetration. For calcium silicate masonry units the absorption typically varies inversely with the compressive strength and maximum levels are assigned for freeze-thaw durability.

Arriscraft calcium silicate masonry units have been independently tested to ensure that they meet and exceed the severe-weathering requirements for ASTM C73.

Freeze-Thaw Durability

The best indicator of satisfactory durability of any masonry unit is its proven performance under similar conditions of use. Arriscraft calcium silicate masonry products have over a 50-year history of achieving excellent durability in a variety of climatic conditions and installations.

Laboratory tests can also be performed to give a reasonable confidence in the CSMU's performance. Proper design, detailing and construction of the wall assembly are critical to long-term masonry performance. (*ref. Drysdale, Hamid, Baker; Masonry Structures – Behavior and Design - Second Edition, 1999; pg. 117*). It must be acknowledged that under extreme service conditions, even product with an excellent history of durability might fail.

Given that a freeze-thaw test is a performance-based test, the freeze-thaw performance of calcium silicate products should be compared to other materials that would be used in the same unit masonry applications. The U.S. industry standard test method for freeze-thaw performance is ASTM C67-03a, *Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile*, a freezing and thawing test method for clay brick masonry. In Canada calcium silicate masonry units would most appropriately be tested in accordance with the Test for Freezing and Thawing as described in CAN3-A82.2-M78 (Reaffirmed 2003), *Methods of Sampling and Testing Brick*.

The same performance criteria as those used for evaluating clay facing brick (defined in either ASTM C216-04, *Standard Specification for Facing Brick (Solid Masonry Units Made From Clay or Shale*) or CAN/CSA-A82.1-M87 (Reaffirmed 2003) *Burned Clay Brick Solid Masonry Units Made From Clay or Shale*, are also a fair measure of performance for calcium silicate products. Both clay brick standards stipulate a maximum allowable loss in weight of 0.5% with no breakage when tested in accordance with their respective methods.

It has been suggested that freeze-thaw tests utilizing saline solutions are necessary for evaluating freeze-thaw durability of masonry veneer products. Masonry veneer products, however, are intended to be used above grade and should not be directly exposed to a de-icing salt environment. Using a saline-based freeze-thaw test, therefore, would not be relevant.

A good quality calcium silicate masonry unit will exhibit exceptional durability when subjected to the above-referenced standard freeze-thaw tests. For instance, when Arriscraft CSMU are tested, they yielded no net loss in weight and they were in excellent condition with no observable signs of distress.

Aesthetic Considerations

At the very least manufacturers must meet the criteria for acceptance pertaining to aesthetic acceptability that are outlined in the applicable standard. ASTM C73 stipulates chips or cracks shall not be visible from a distance of 20 feet. It further states that 5% of a shipment containing chips no larger than ½" or cracks no wider than 0.02 inches and not longer than 25% of the nominal height of the unit is permitted.

Where the nature of the finish necessitates a restriction on chippage, better quality calcium silicate masonry units exceed these criteria. For example, smooth finished Renaissance® Masonry units are inspected to be free of chips, cracks or other blemishes on the finished face or front edges of the material exceeding 10 mm (3/8") or that are objectionable from a distance of 3 m (10'-0"). Units provided with rusticated faces are inspected for cracks and blemishes only as chippage considerations do not apply when the desired surface texture and unit shape is intended to be uneven.

Good quality calcium silicate masonry units must also be packaged to maintain this level of good quality

during shipment. The masonry contractor is expected to take the proper precautions during storage and handling. Recommendations are contained within the ARRISCRAFT•CARE sheet. Any damaged, chipped or broken product that arrives on site should be brought to the attention of the manufacturer prior to the installation as installation constitutes acceptance of the product.

Movement Characteristics

Dimensional change of a material resulting from changes in temperature is expressed by its coefficient of thermal expansion. Similarly, changes in moisture content over the service life of a building will result in dimensional changes. This property is often expressed as a strain or a percentage based on the material's initial length at ambient conditions. The movements caused by thermal and moisture changes are generally not additive. Actual movement in a masonry wall will be affected by both the unit age and degree of unit saturation at the time of construction and the temperature and humidity conditions to which the wall is exposed. These types of movements are cyclical in nature (e.g. reversible).

Typically, clay bricks undergo a permanent moisture expansion over the life of the brick; whereas, cement-based units undergo a degree of permanent shrinkage. While some sources site a permanent shrinkage of calcium silicate units, with better quality CSMU any shrinkage would only occur very early in the life of the unit, during the production process. It is imperative, therefore, that the building movement joints in a CSMU veneer be designed and constructed as *elastic* joints so that they can accommodate the associated cyclical expansion and contraction of the masonry veneer due to temperature and moisture conditions.

When determining the placement of the building movement joints, the building designer must consider the cyclical movement characteristics of the masonry unit. Values for thermal movement and reversible moisture movement of CSMU are within the same range as those for clay units. Thus, required placement and spacing considerations for movement joints would be similar. For further information on the proper design and detailing of movement joints, refer to ARRISCRAFT•NOTE, Vol. I, No. 1, titled Building Movement Joints.

Summary

This ARRISCRAFT•NOTE discusses the properties of calcium silicate masonry units (CSMU), including the applicable reference standards, physical characteristics, freeze-thaw durability and cyclic volumetric changes. CSMU are not the same as clay brick or concrete-masonry products, and their properties are sufficiently distinct to warrant some consideration during the design of a building.

Calcium silicate masonry units are a manufactured masonry product offering a wide variety of distinctive colours and textures, closely simulating the appearance of many natural stones. They provide building designers with the opportunity to use a material of controlled high strength, with a natural appearance and a well-established durability at an economical cost.

The information and suggestions contained herein are based upon the available data and information published by the listed references and the experience of Arriscraft International architectural and engineering staff. More detailed information may be found by referring to any of the related references listed below.

The information contained herein must be used in conjunction with good technical judgement and a competent understanding of masonry construction. Final decisions on the use of the information contained in this ARRISCRAFT•NOTE are not within the purview of Arriscraft International and must rest with the project designer or owner, or both. It remains the sole responsibility of the designer to properly design the project, ensure all architectural and engineering principles are properly applied throughout, and ensure that any suggestions made by Arriscraft International are appropriate in the instance and are properly incorporated through the project.

Related References

1. American Society for Testing and Materials, ASTM C67-97, Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile.
2. American Society for Testing and Materials, ASTM C73-97a, Standard Specifications for Calcium Silicate Face Brick.
3. American Society for Testing and Materials, ASTM C216-97, Standard Specification for Facing Brick.
4. Canada Standards Association, CAN/CSA A82.1-M87 (Reaffirmed 2003), Burned Clay Solid Masonry Unit Made From Clay or Shale.
5. Canada Standards Association, CAN3-A82.2-M78 (Reaffirmed 2003), Methods of Sampling and Testing Brick.
6. Drysdale, Hamid, Baker; Masonry Structures - Behavior and Design - Second Edition, The Masonry Society, 1999.

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