

National Concrete Masonry Association
an information series from the national authority on concrete masonry technology

COMPRESSIVE STRENGTH TESTING VARIABLES FOR CONCRETE MASONRY UNITS

TEK 18-7

Quality Assurance & Testing (2004)

Keywords: block-mortar strength, bond strength, eccentric loads, moisture, stress distribution, testing

INTRODUCTION

Anyone engaged in testing concrete masonry units or prisms, or interpreting test results, should be familiar with testing variables and their significance. Variables both prior to and during testing may significantly influence test results. Tests conducted to establish design criteria will affect the wall sections selected, and often will have a direct effect on the economics of the building.

Except for certain architectural facing units such as split block and slump block, concrete masonry units are manufactured to relatively precise dimensional tolerances. Because of this, it might be assumed that the units are not sensitive to variations during testing, although this is not necessarily true. Changes in concrete masonry unit moisture content can cause changes in the physical characteristics. Increases in moisture content of concrete masonry units at the time of testing reduces compressive strength. Volume change can also be influenced by the presence of moisture. Upon drying, concrete masonry units undergo shrinkage.

These conditions, i.e., strength gain and volume change, may occur simultaneously during the test period. Consequently, the effect of variables on the strength properties of the unit should be known. Testing, per se, thus becomes a conscientious effort to exclude known variables, adhere to prescribed testing methods, and present true test results.

This TEK discusses variables which may be encountered during testing of concrete masonry units. The person performing tests, and the person interpreting results, should assure themselves that all necessary precautions have been taken to render variables insignificant, or preferably nonexistent.

APPLICABLE STANDARDS

Compressive strength testing procedures for concrete masonry units and other related products are covered by ASTM C 140, *Standard Methods of Sampling and Testing Concrete Masonry Units*. By reference to other standards,

items such as the requirements for the testing machine are covered. The completeness of these test methods disallows much variation. Strict adherence to the laboratory procedures outlined in this standard test method is critical to obtaining accurate results.

Both the tester and the interpreter should have a working knowledge of the procedures in ASTM C 140, the effects of test variables on results, and the requirements of the product specification which establishes minimum criteria for the unit being tested.

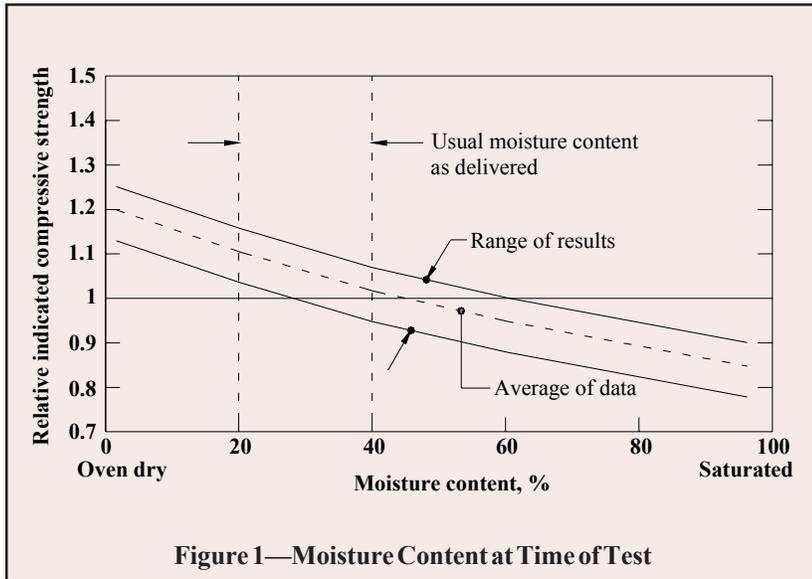
VARIABLES

Variables which may influence the reported test value include the test specimen and its preparation, the physical testing machine, the tester's use of the machine, the placement of the specimen within the machine, plate thickness for compression testing, and the testing procedure used.

Variables in the concrete masonry unit that can influence the test results include the moisture content of the concrete masonry unit at the time of test and the geometry (shape) of the concrete masonry unit.

Moisture Content of the Concrete Masonry Unit at Testing

The moisture content of the concrete masonry unit at the time of test may have a significant effect on the reported test value. Testing of concrete masonry at various moisture contents, Figure 1, has demonstrated that moisture content may be responsible for a higher or lower reported test value. Oven-dry units possess higher tested compressive strengths than their normal (air-dry) moisture content counterpart. Conversely, concrete masonry units tested wetter than their normal counterpart yield lower compressive strengths. The approximate twenty percent increase or decrease is significant. This finding strongly suggests that sampled units destined for compressive strength testing should be maintained



in their “as-received” or “as-desired” moisture condition. To help ensure this, ASTM C 140 requires that units be stored until tested in air at a temperature of 75 ± 15 °F (24 ± 8 °C) and a relative humidity of less than 80%, and not be subject to oven drying.

The cause for this strength increase-decrease is attributed to secondary hydraulic pressure which develops as the unit and water within the unit are subjected to external pressure. The loads are additive, so higher moisture contents yield larger strength reductions. Conversely, an oven-dry specimen possesses internal tensile strains, which must be overcome by compressive forces before the strains become compressive.

Reducing the moisture content of a specimen is even more significant when testing involves tensile strength properties, bond strength, or flexural strength. The strength reduction is greatest at the early period after specimen relocation to a drier environment. Again, maintaining the test specimen in the steady or equilibrated state is the proper way to conduct testing.

The moisture condition of concrete masonry at the time of testing may alter the true load carrying capacity of the unit.

Geometry (Shape) of the Test Specimen

Any material being tested, using test sections with various heights while maintaining a constant cross section, will yield higher compressive strengths as the ratio of the height to thickness of the specimen decreases. A tall specimen possesses a lower load carrying capacity than a short or shorter specimen. Test specimens subjected to compressive loads fail through a combination of compression and tension. Tall specimens are more sensitive to the influence of tensile stress, while short specimens fail in bearing.

Although the general trend toward strength reduction is known, the height to thickness ratio (h/t) influence normally used to identify specimen shape effects varies with aggregate type, concrete masonry strength, moisture content, etc.

A concrete brick from the same mixture used to produce a concrete block may have a higher apparent compressive strength than its block counterpart. The shape effect contributes as does the degree of consolidation during manufacturing and the effectiveness of unit curing.

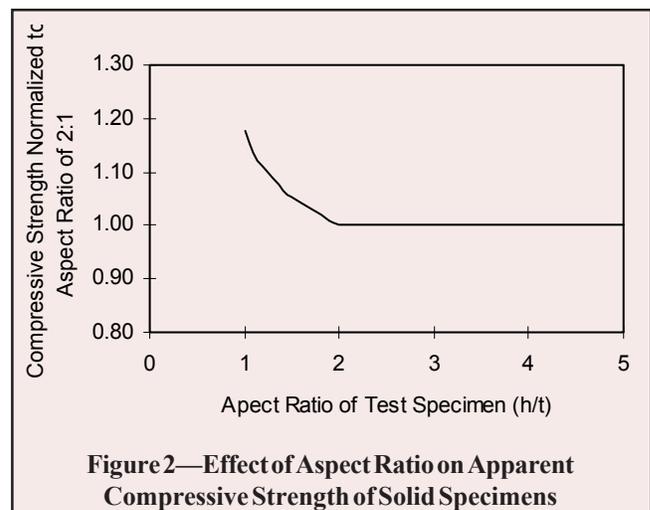
ASTM C 140 includes h/t correction factors for segmental retaining wall unit specimens with aspect ratios less than two. When coupons are used as compression specimens, they are cut at an h/t of 2, so correction factors are not needed. Figure 2 illustrates the effect of aspect ratio on apparent compressive strength of solid specimens. Hollow concrete masonry units are less affected by variations in h/t . For example, research has shown little change in apparent compressive strength when the unit height is reduced by one-third or less.

Tester Influenced Variables

A laboratory technician may significantly alter the failure compression test load, either consciously or unconsciously. Technician procedural influences include: (1) selection and maintenance of the physical testing machine and its accessories, such as bearing blocks and testing plates; (2) selection of capping material and application of a proper cap; (3) the positioning of the specimen for test; and (4) the rate of loading. Singly or collectively, these factors will influence the failure load. It is of interest to note that these variables, with the exception of a rapid rate of loading, will cause a lower reported failure load.

Testing machines should conform to the requirements of ASTM E 4, *Practices for Force Verification of Testing Machines*. The verification of the testing machine occurs under different loading conditions than those that prevail during actual test. The accessories such as bearing block or plates, and thin plates which deflect during loading, cause the same strength reduction discussed below for imperfect caps. Oil on the plates of the machine will also reduce the failure load result.

Capping materials vary in composition and, conse-



quently, so does their modulus of elasticity. Approved (ASTM C 1552 *Practice for Capping Concrete Masonry Units and Masonry Prisms for Compression Testing*) capping compounds include mixtures of 40 to 60% sulfur and ground fire clay and other suitable material passing a No. 100 (150 μm) sieve or high strength gypsum cement. The use of alternate materials should not be permitted. Fiber board or other similar materials will compress more readily than their approved counterpart. Compressing the fiber board causes it to spread laterally, inducing tensile stresses into the test specimen and resulting in a lower apparent compressive strength. The resulting strength may still allow product certification if the strength value surpasses the minimum specified value. Results can vary from twenty to forty percent below the properly capped counterpart value. Because the compression results are conservative, many block producers use this less-labor intensive method as a means of assuring their compliance with specified minimum compressive strengths.

Capping materials that are not properly applied to the unit may be responsible for nonuniform stressing of the specimen during loading. A fifteen percent loss in strength has been measured for units improperly capped.

ASTM C 1552 requires the capping plate to be plane and rigid enough not to deflect during capping. Deflection of the capping plate results in a crown on the testing surface of the units, leading to nonuniform load distribution and lower apparent compressive strengths. One-half inch (13 mm) thick glass plates placed on top of 1 in. (25 mm) thick steel plates are recommended. The glass plates provide a smooth scratch-resistant replaceable wear surface while the steel plates provide needed stiffness to the capping station.

Similarly, the steel bearing plates on the compression testing machine must be rigid enough not to deflect during testing. Small deflections, unnoticeable to the naked eye, will negatively impact test results. ASTM C 140 requires that the steel bearing plates have a thickness at least equal to the distance from the edge of the spherical bearing block to the most distant corner of the specimen. This thickness must be achieved by using a single plate having a width and length at least $\frac{1}{4}$ in. (6.4 mm) greater than the length and width of the specimen being tested. Stacking several plates to reach the required plate thickness will be less rigid than a single plate of the required thickness. It is also required that the bearing faces of the plates have a Rockwell hardness of at least HRC 60 (BHN 620).

Oil on the testing plates or platens of the testing machine, or the capped surfaces of the test specimen, will also reduce the failure load. The oil lubricates the interface between specimen and machine. The result is that the test specimen expands at the interface; tensile failure occurs sooner and at a lower load.

Positioning of the test specimen within the machine can have a significant effect on the failure load. For units that are essentially symmetrical the positioning is important, but to a lesser degree than when unsymmetrical units are being tested. The applied load of the testing machine should pass through the centroid of the test specimen. Units tested with

Table 1—Checklist For ASTM C 140 Testing

Frequency of Sampling

6 units per first 10,000.
12 units per 10,000 to 100,000.
6 units for each 50,000 or fraction thereof for lots of more than 100,000.

Action Upon Receipt

Place identifying mark on each specimen but not to cover more than 5% of the superficial area of the specimen.
Immediately weigh moisture control units.

Capping Test Specimens

Use rigid, smooth, level, and plane capping station.

Sulfur Materials

Use mixtures consisting of 40 to 60 percent sulfur.
Capping surface to be plane within 0.003 in. in 16 in. (0.075 mm in 400 mm)
Thickness of cap < $\frac{1}{8}$ in. (3 mm)
Cool cap > 2 hr. Replace imperfect caps.

Gypsum Plaster

Plaster to have compressive strength >3500 psi (24.1 MPa) at 2 hrs. when tested as 2 in. (51 mm) cubes.
Average thickness of cap < $\frac{1}{8}$ in. (3 mm)
Age caps > 2 hrs. prior to testing. Replace imperfect caps.

Testing Procedure

Positioning of Specimens

Align centroid of bearing surface with load center.
Cores of hollow units to be vertical except for special units intended for use with hollow cores horizontal.
Test all other units in direction as used in service.

Speed of Testing

Apply one half expected load at convenient rate.
Apply remaining load > 1 and < 2 min.

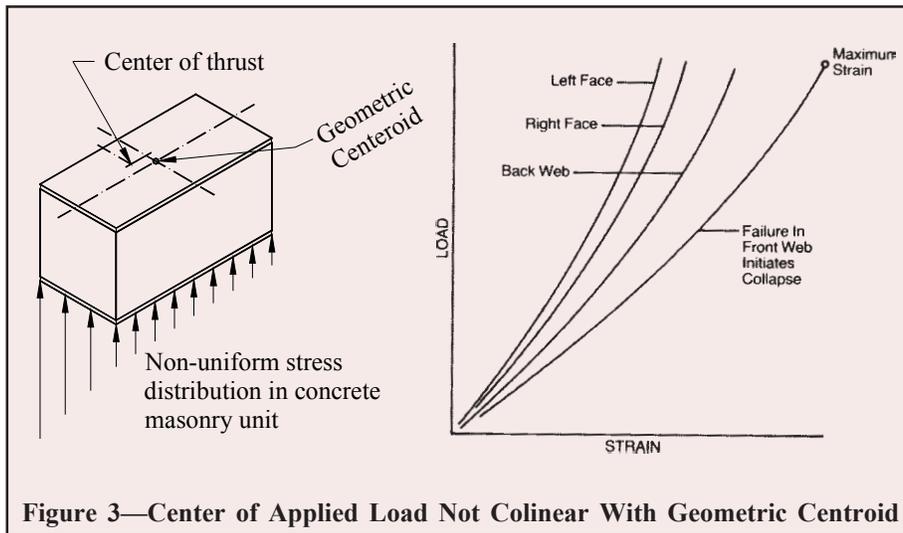
Applicable ASTM Standards

Specifications

- C 55 Concrete Brick
- C 90 Loadbearing Concrete Masonry Units
- C 129 Nonloadbearing Concrete Masonry Units
- C 936 Solid Interlocking Paving Units
- C 1319 Concrete Grid Paving Units
- C 1552 Practice for Capping Concrete Masonry Units, Related Units, and Masonry Prisms for Compression Testing
- E 4 Practices for Force Verification of Testing Machines

Test Methods

- C 140 Sampling and Testing Concrete Masonry Units
- C 426 Drying Shrinkage of Concrete Block



applied load other than at the centroid can provide an array of reported values, Figure 3. Loads not applied through the center of mass of the unit results in lower tested strengths and increased variability in results.

For masonry units that are symmetrical about an axis, the location of that axis can be determined geometrically by dividing the dimension perpendicular to that axis (but in the same plane) by two. For masonry units that are nonsymmetrical about an axis, the location of that axis can be determined by balancing the masonry unit on a knife edge or a metal rod placed parallel to that axis. If a metal rod is used, the rod must be straight, cylindrical (able to roll freely on a flat surface), have a diameter of not less than $\frac{1}{4}$ in. (6.4 mm) and not more than $\frac{3}{4}$ in. (19.1 mm), and it must be longer than the specimen. Once determined, the centroidal axis is to be marked on the end of the unit.

Speed of Testing

The compression machine operator can also influence the test value by altering the rate of loading. Generally, rapid loading of a specimen will yield a higher apparent failure

load than the less rapid or normal rate of loading. Loading should occur at some convenient rate to approximately one-half of the expected ultimate load. Thereafter the rate of loading should be adjusted such that failure occurs within the period from 1 to 2 minutes.

SUMMARY

The primary objective of testing concrete masonry units is to establish product quality for acceptance and to aid the design engineer toward selection of materials and their combination in the most economical wall section or structure. Unchecked variables during product testing invariably increase the cost of the wall. The effects of these variables will be lessened by conforming with the requirements highlighted in the checklist, Table 1.

Unless controlled, testing variables will influence tested strength properties of concrete masonry. Variables which will result in higher compressive strength include the geometry (shape) of the specimen, rapid rate of load application, and low moisture content at the time of testing. Other testing variables such as improper application of the capping material, high moisture content at time of test, use of "thin" bearing plates, and improper positioning in the compression machine, will reduce the failure load value. Both extremes should be avoided.

Accurate and correct tested values are critical to masonry construction and design. Conservative results increase the factors of safety for design, but may result in uneconomical construction. The cost required to resolve compounding errors in judgement resulting from inaccurate testing is much greater than the cost required to use and maintain the right equipment and to properly train testing technicians to understand the effects of those variables discussed here.