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# CONSTRUCTION AND TESTING OF MASONRY PRISMS: FAILURES AND REMEDIES

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## ABSTRACT

The Uniform Building Code (UBC) and American Society for Testing and Materials (ASTM) contain criteria for prism testing methods to determine the strength properties of pre-construction, construction and in-place masonry. Successful prism test results verify that a masonry building system meets the design standards, but prism failures do not necessarily mean that the system does not meet the design criteria. In the event of prism failures, it is important to review the prism construction process and the test procedures to determine obvious errors. It is also significant to understand that other tests can be performed to determine the strength of the masonry in the event of prism test failures.

## INTRODUCTION

Masonry prisms are an important element of current design and construction procedures. The latest design procedures, including the Limit States Design, rely heavily upon quality controlled construction in order to obtain proper strength levels that assure the successful performance of masonry under adverse loading conditions

The construction of masonry with an $f'_m$ of up to 27,800 kPa (4,000 psi) is possible when masonry prism testing is used to confirm the compressive strength of the installed masonry

A masonry prism is an assemblage representative of the actual construction and is built for the sole purpose of testing to determine the ultimate compressive strength. The minimum prism size is dictated by the governing code, and the prism must also be small enough to fit into the testing apparatus.

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The UBC is recognized as the governing code for the Western half of the United States and UBC Standard 21-17 dictates the criteria for masonry prisms. Another nationally recognized Building Code, as reported by the Masonry Standards Joint Committee, is the Building Code Requirements and Specifications for Masonry Structures (ACI 530). ACI 530 recognizes ASTM E 447 as the guideline for constructing and testing of masonry prisms.

## PRISM CONSTRUCTION

A comparison of the two methods in constructing and testing masonry prisms, UBC Standard 21-17 and ASTM E 447, reveal very little difference. Items noted are given in Table 1.

### TABLE 1 — COMPARISON OF PRISM TEST METHODS

| **Item** | **UBC/UBC Standard 21-17** | **ACI 530.1-92/ASTM E 447** |
|---|---|---|
| Prism Height | 2 Units, but not less than 1.3 times actual thickness | 380 mm (15 inches), but not less than 2 times thickness |
| Mortar Joints | At least 1 | At least 2 |
| Planar trueness of test bearing plate | $\pm$ 0.0254 mm (0.001 in.) in 150 mm (6 in.) | $\pm$ 0.003 mm (0.0001 in.) in 150 mm (6 in.) |
| Initial Prisms | 5 required | Not specified |
| Frequency of prisms | 3 every 465 $m^2$ (5,000 sq. ft.) | When required |
| *h/t* Ratio | 1.30 to 5.0 | 2.0 to 5.0 for brick<br>1.33 to 5.0 for CMU |
| Correction Factor | Same for CMU & Clay | Different for CMU & Clay |
| Bonding Arrangement | Stack Bond | Method A-Stack bond<br>Method B-Same as project |

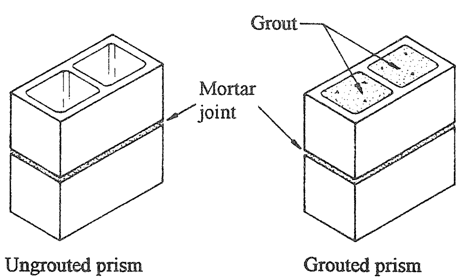


Fig 1. Prisms constructed in accordance with UBC Standard 21-17

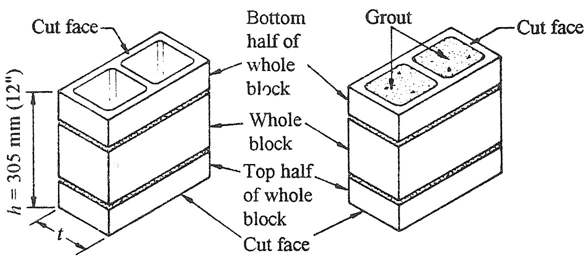


Fig. 2. Prisms constructed in accordance with ASTM E 447

The following analysis considers the UBC prism guidelines

For an effective prism testing program, careful planning is required. Since test results are required prior to construction, prisms must be constructed long before the normal jobsite activities. The conditions must duplicate the project conditions, as much as possible. If the grout is to be transit mixed, then the grout for the prisms should be batched according to the project specifications and transit mixed.

The *h/t* ratio of the prism must be at least 1.3 and not greater than 5.0. The machines used for testing prisms are also used for testing concrete cylinders, and the sample capacities are commonly 400 mm to 460 mm (16" to 18") (Drysdale et al 1994). Since the Standard requires prisms of at least 2 units in height and CMU are 200 mm (8"), CMU prisms in excess of 2 units in height are uncommon. Clay brick prisms are normally 300 mm to 400 mm (12" to 16") in height. Figure 3 shows prism configurations that are large enough for Code conformance, yet small enough to be tested.

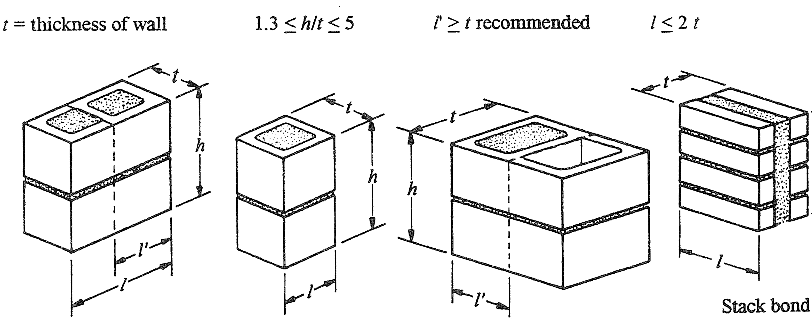


Fig. 3 Sizes of masonry prisms

The project specifications must be very precise in the selection of the masonry unit, for example, a high-strength, 25,900 kPa (3,750 psi) 190 mm x 190 mm x 390 mm (8" x 8" x 16"), Type I Concrete Masonry Unit conforming to ASTM C-90-94. Additionally, the mortar and grout must be selected and clearly stated, for example, type M mortar, by proportion, conforming to ASTM C 270 or UBC Standard 21-15, and coarse grout conforming to ASTM C 476-91, with a minimum grout compressive strength of 25,900 kPa (3,750 psi). When a design mix for the grout is required, more lead time is required for the submittal process before the prism is constructed.

Under UBC Standard 21-17 prisms are always constructed in a stack bond configuration with fully mortared bed joints, that is, the face shells *and* the cross webs receive a full mortar bed. The significance of constructing a prism in running bond is shown in Fig. 4, where lateral restraint of the half units is not present. The lack of lateral restraint combined with the half units forms a vertical plane of weakness that does not exist in the installed masonry. Under this condition, splitting of the prism will occur at a compression value less than the actual wall conditions.

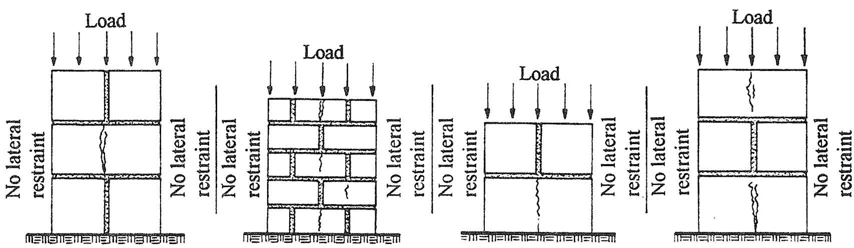


Fig. 4 Running bond prisms with no lateral restraint on half units.

Curing considerations are given by constructing the prisms on and sealing in, a plastic moisture tight bag. This bag is sealed immediately after construction of the prism.

When the masonry is to be solid grouted, the prisms shall also be solid grouted. If the masonry is partially grouted, two sets of prisms are constructed and one set is grouted solid, while the other set is not grouted. Since the prisms are tested for compression, the structural reinforcement is never placed in the prism. When appropriate, wire ties may be included to hold together 2 wythe masonry construction.

The grouting operation is performed between one and two days after the construction, and the prism is to be left undisturbed for at least two days after completed. The prisms may then be carefully transported to the laboratory for testing.

## MULTIWYTHE MASONRY

Construction of a multiwythe grouted system may require prism tests, however, the UBC Standard clearly states that each wythe of the masonry, for prism testing purposes, shall be tested separately. A position in support of this method is that if each wythe is designed for different strengths, such as 20,700 kPa (3,000 psi) and 27,600 kPa (4,000 psi), respectively, this individual wythe prism test approach can verify the field conditions, and the variables involved are reduced. As a result, the test results should consistently verify the individual wythe strengths.

On the other hand, consideration must be given to the total compressive capability of the **entire** masonry system and this result can only be accomplished by testing a prism composed of wythe-grout-wythe, face of wall to face of wall. When the compressive capabilities of the individual elements are different, along with possible differences in the moduli of elasticity, the importance of testing the complete prism assemblage cannot be overemphasized.

Unfortunately, the Standard does not yet recognize the requirement for testing more than the individual wythes in a multiwythe system.

## TESTING

Prior to transport, the prisms are protected from damage by strapping or banding, then moved to the laboratory without bouncing or falling over

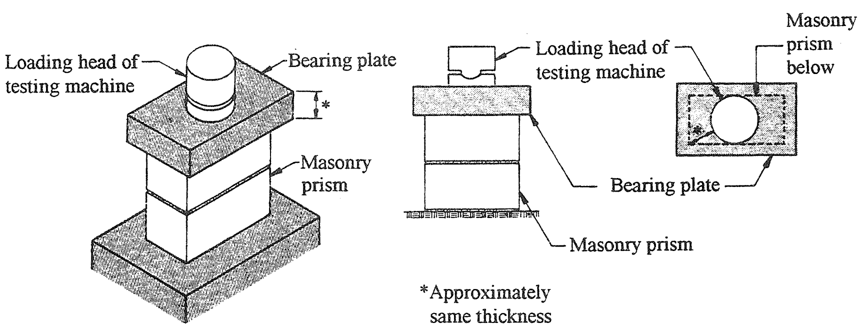


Fig. 5 Masonry prism compression test

Once in the laboratory, the prisms remain in the sealed bag until two days prior to testing. The environment for prisms over the last two days should be 24° C ± 8° C (75° F ± 15° F).

The prisms are capped, both top and bottom, so that a planar, level surface is formed within very strict tolerances. This careful procedure attempts to eliminate the variable of eccentricity when the prism is compressed to failure.

Half of the expected minimum load is applied at any convenient rate and the balance of the expected load is applied at a uniform rate with a time duration between one and two minutes. Figure 5 depicts the prism under testing conditions. Note that thickness of the bearing plate should be approximately equal to the distance from the machine loading head to the most extreme vertically projected point of the prism. Bearing plates of inadequate thickness can lead to inaccurate test results.

## ALTERNATIVES

Notwithstanding all of these precautions, test results may be inadequate for the design of the building. Before the masonry is structurally rejected and removed, there are other tests available that can accurately determine the compressive wall strength.

*Coring*

The Division of the State Architect (DSA) for California adopts the Uniform Building Code, as amended, for their design and construction requirements. Part of the amendments include a provision for coring constructed masonry.

DSA mandates that half the cores be tested for shear and the balance are available for compression testing. As shown in Fig. 6, the core is drilled from the wall horizontally, usually avoiding mortar joints, as well as wall reinforcement.

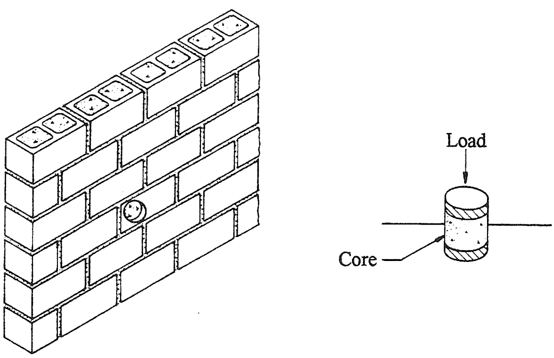


Fig. 6 Test core from wall with full load applied through all specimen components

During the coring process, it is common for the face shell of structural concrete masonry to separate from the grout. This is not an indication of inadequate bond between the masonry unit and grout. The vibration and pressure of the drill exerts abnormal conditions upon the masonry components.

When the face shell separates from the core in the drilling process, it advisable to discard the core and drill another. After successful removal, the core must be thoroughly dry before testing.

Since the core test is in the weak horizontal direction, whereas actual compression loads are imposed in a vertical direction, an adequate core test is normally a good indicator that the masonry systems contains adequate compressive strength. While it is true that the mortar is not tested, and that dissimilar engineering properties between imposed vertical loads of the grout and masonry unit are not actual loading conditions, the offset is the substantial agitation during the drilling of the core sample.

The coring method is not contained in the masonry section of the UBC, therefore, many jurisdictions do not rely on the test results, however, the testing of in-place masonry prisms is available.

*In-Place Prisms*
When constructed prisms do not meet the design strength requirements, the Uniform Building Code allows for prisms to be cut from the constructed masonry. Prism size is in accordance with UBC Standard 21-17, that is, at least 2 units in height, with an *h/t* ratio between 1.3 and 5.0.

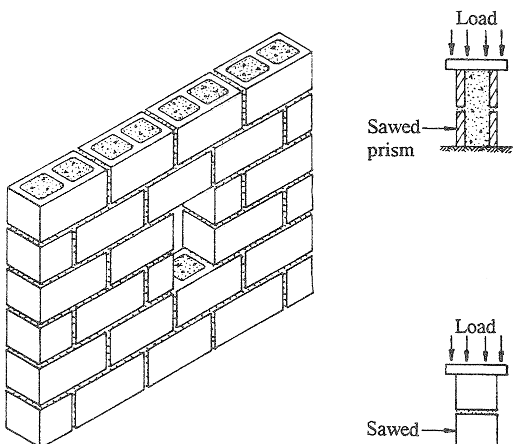


Fig. 7 Test of In-Place prism cut from wall

Cutting of the prisms must be done with a minimum of disturbance. First, the location(s) must be selected so that cutting through reinforcement is avoided. The cutting equipment should generate minimum vibration. The operator must understand the proper cutting sequence. The constructed masonry must be at least 28 days old before the prisms are cut.

The bottom of the prim must be the first cut and immediately shimmed from both faces of the wall to avoid any drop of the prism. Next, one of the vertical cuts is made, and immediately shimmed at both wall faces followed by the other vertical cut, which is also shimmed in the same manner. Finally the top of the prism is cut, and the prism is carefully removed Extreme care must be taken in transporting the prism to the laboratory in order to minimize disturbance.

Once in the laboratory, the prism can be capped and tested for compression. Using a laboratory with experience in prism testing is highly recommended. It is not unusual for the in-place prism testing to be performed by a laboratory that is different from the laboratory used during the construction testing. Higher test results at a second independent laboratory should be deemed reliable.

## ALTERNATIVE ANALYSIS

Occasionally, the test results will remain low which strongly suggests that the structural strengths do not meet the required specified strengths. Unfortunately, the construction work following the installation of the masonry usually prohibits replacement of the brick or block.

If this situation should occur, the matter must be submitted to the project Structural Engineer for resolution. Recalculation of the required design strengths may be sufficient, or remedial work, such as additional lateral bracing, or skin reinforcement, such as gunnite, may be required. There is no one cure-all answer for this infrequent problem, but the solution is attainable with experience and cooperation of the involved parties.

Anything less usually creates costly litigation.

## SUMMARY AND CONCLUSIONS

The concept of masonry prism testing is easy to understand and difficult to achieve with absolute predictability. Building Codes that provide for prism testing also provide specific means for constructing and handling the prism specimens.

When the test results are less than adequate, the variables of curing, handling, and testing procedures must be reviewed for compliance. Additional testing should be conducted by using the wall core method, or the in-place prism test method, or both.

In the rare cases where the additional testing cannot confirm adequate wall strengths, the matter must be referred to the Structural Engineer for further analysis or remedial consideration.

In most cases, actual wall strengths are readily confirmed with prism testing, which, in turn, allows for the successful performance of masonry when exposed to intense wind and seismic forces.