8TH CANADIAN MASONRY SYMPOSIUM

Jasper, Alberta
May 31 - June 3, 1998

THE SIGNIFICANCE OF MASONRY INSPECTION

John Chrysler
Executive Director
Masonry Institute of America
Los Angeles, California

ABSTRACT

The rapid development of technology in the second half of the 20th century introduces a dilemma to the construction process. Computers can make the masonry construction design process so precise that unachievable construction tolerances are required. The mason contractor is under constant demand to complete the project in a timely manner, to an unrealistic schedule, within budget, which is usually understated, and with construction quality that is second to none. Issues of schedule and bidding are not contained in this paper. This paper addresses the issues associated with the high level of quality anticipated by the architect and developer and the minimum level of quality, which is the goal of the contractor. A logical attempt to resolve the two levels of quality is through a realistic inspection process. It is also important for the reader to understand that this paper addresses the issues of structural integrity, not aesthetics.

KEYWORDS

Quality, quality assurance, inspection, masonry inspector, design, masonry

INTRODUCTION

Many prominent and knowledgeable individuals have contributed countless hours in the development of the Quality Assurance program about to be published in the *Building Code Requirements for Masonry Structures* (ACI 530-98/ASCE 5-98/TMS 402-98). A considerable effort was made to establish proper guidelines for an effective masonry inspection procedure. As one can imagine, a single inspection procedure does not satisfy the multiple levels of Code requirements, therefore, certain thresholds were established in order to best satisfy the parties involved with Quality Assurance issues.

HISTORY

The Uniform Building Code first required continuous inspection of structural masonry some 55 years ago in 1943. It was permissible to design and construct masonry that was not continuously inspected, however, the design stresses were then limited to 50% of those allowed by the masonry section of the code. This was an arbitrary penalty for masonry that was not continuously inspected, but has been used successfully in the Uniform Building Code for the past 55 years.

In the 1970's, industry published the *Building Code Requirements for Concrete Masonry Structures* (ACI 531), and *Specification for Concrete Masonry Construction* (ACI 531.1), which has since evolved to the *Building Code Requirements for Masonry Structures* (ACI 530/ASCE 5/TMS 402) and the *Specification for Masonry Structures* (ACI 530.1/ASCE 6/TMS 602), reported by the Masonry Standards Joint Committee. Industry fully anticipates that the International Building Code will adopt the ACI 530 by reference as the major part of the single model code for the United States, slated for publication in the year 2,000.

A fundamental assumption of the *Building Code Requirements for Masonry Structures* (ACI 530) is that masonry is constructed in accordance with a quality assurance program, however, the requirements of a quality assurance program have been somewhat ambiguous. Every one of the six sentences addressing inspection requirements in 1995 edition of ACI 530 contain the words "when required". If not required, then no inspection of the masonry is a realistic option, and the possibility of construction not meeting the design criteria increases.

Recognizing this possibility, a task group was formed in 1995 to develop specific and required inspection guidelines to be applied to ACI 530. The committee contained representation from throughout the United States and all shared the common concern for construction quality assurance through the masonry inspection process.

A great deal of time was spent on the terminology and understanding of the role of the masonry inspector. Some of the committee members had reservation of the term 'Special Inspector', however, the term as defined in ASCE 7-95 clearly recognizes the Special Inspector as one who shall be identified as the Owner's Inspector. The significance of the inspector bearing allegiance to the owner cannot be overemphasized.

THE CONSTRUCTION PROCESS

Capitalism in the free world encourages the competitive drive in humans. It is not unusual for a person of marginal intelligence to learn a specialty trade, such as bricklaying, and in the drive to achieve success, this individual may very well decide to exercise his bricklaying skills for his own benefit, rather than under the wing of an employer. This method has been the beginning of many successful and well run mason contractors.

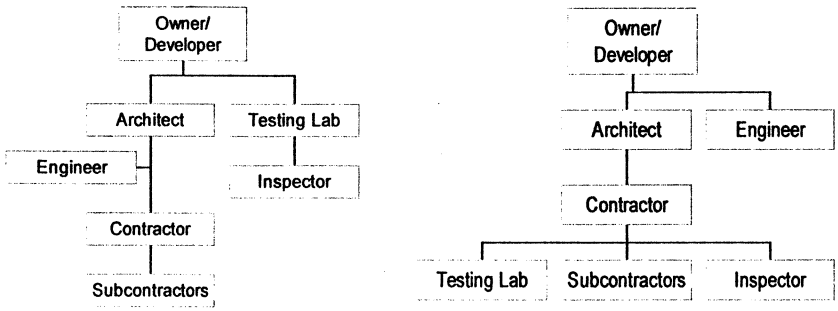
In order to acquire a sufficient amount of work to keep a successful business thriving, the contractor must be cost competitive. Once the masonry contract for the project is signed, the contractor is totally reliant upon his workforce for a successful project. There are also many other factors that contribute to the success of a project, but this paper will assume that those factors do not play into the success equation.

Masonry is an installation of many units and mason contractors typically use the instantaneous gauge of production to measure progress on a daily basis. The project bid will contain the total number of units and the total labor, which divides into a production rate. The rate of number of units laid to date, divided by total labor used to date, will produce an actual comparative number. By achieving a production rate equal to or higher than the bid production, the contractor readily produces a gross profit, thereby increasing the chance for perpetuating his business.

On the other side of the construction equation is the project owner who expects as much quality as can be delivered into the project, notwithstanding the minimum construction quality thresholds the contractor anticipates.

This dichotomy of opinions can be successfully resolved with a less than neutral party, the masonry inspector. The tools of the mason are a level and trowel while the tools of the inspector are the code book and a report form. The two parties actually have parallel paths to a common goal, successful project completion.

The inspection organization chart of ACI 530-98 is not as well defined as that in the Uniform Building Code. Figure 1(a) depicts the organization structure as currently required by the Uniform Building Code. One possible scenario allowed by the new inspection guidelines of ACI 530 is characterized in Figure 1(b). It should be obvious that the scenario presented in Figure 1(b), with the inspector answering to the contractor, is woefully inadequate for an effective masonry inspection program.



(a) Inspector responsible to owner (b) Inspector responsible to contractor

Figure 1 Construction team organization chart

THE CODE THRESHOLD

One of the most important issues to understand about the building code, any building code, is that it requires a minimum threshold for design and construction. Figure 2 shows an arbitrary scale wherein 70% quality would satisfy minimum code requirements. The 85% quality level would be classified as superior quality and 100% would be of the highest quality. Consider the Architect or Engineer who designs a building to a higher quality standard (90%), only to have a contractor provide the level of quality required by the code. In order to assure that the structure meets the intended design, it is important for the design professional to clearly indicate in the plans and specifications what is required in addition to the code requirements *and* to have a neutral party observe the construction on behalf of the building owner.

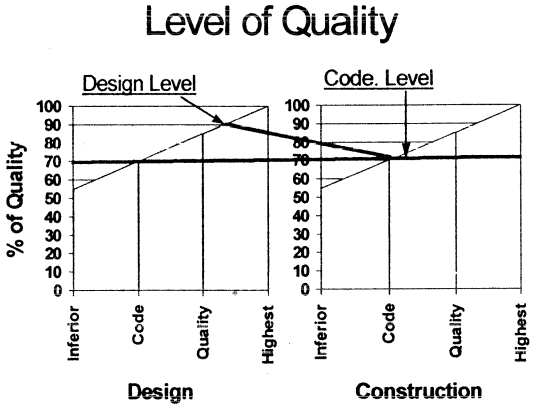


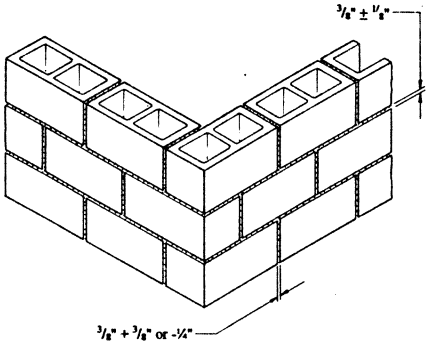
Figure 2 Comparative Design-Code quality chart

Appendix A.9 in ASCE 7-95 clarifies the use of special inspection as it applies to structural masonry. This clarification is consistent with the Uniform Building Code inspection provisions of Chapter 17. The two references are very specifically applied to structural masonry, which is more than the finished wall surface. Structural performance of unreinforced masonry is based on the placement of units and mortar bond which can be easily observed or tested after the wall is in place, however, the structural performance of reinforced masonry, that is, reinforced with deformed bars, is highly dependent on condition, location and placement of reinforcing steel, grout compressive strength and grout placement, items that cannot be observed or easily tested once the wall is in place. Closely associated with these hidden elements is the location, placement and grouting of embedded items, such as anchor bolts. These items have structural implications equal in importance to deformed structural reinforcement.

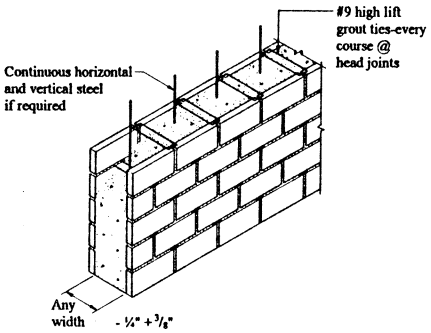
Consequently, there is a requirement for masonry inspectors to understand the structural significance of the materials and construction associated with a reinforced masonry wall. It is not the duty of an inspector to concentrate solely on the aesthetics of a building since structural issues are the primary function of the structural masonry inspector. Appearance of the building may be related to structural issues, such as variations from tolerance.

The Uniform Building Code is silent on tolerances associated with masonry. Certain construction tolerances can be derived from stated material tolerances contained in material standards. For example, ASTM C 90 and UBC Standard 21-4 allow for material tolerances of concrete masonry units $\pm$ $^1/_8$" (3.2 mm) in any given dimension. The difference between the width of two adjacent block units could be $^1/_4$" (6.4 mm) with compliance to material standards.

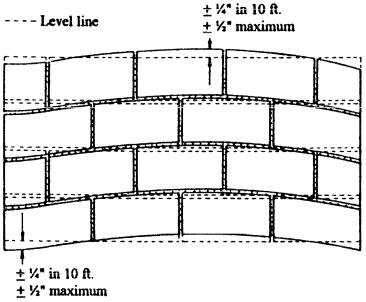
ACI 530.1 states specific permissible construction variation tolerances which are compatible with the material standards. For a more comprehensive understanding of the application of tolerances, the ACI 530.1 Code Commentary states: "Tolerances are established to limit eccentricity of applied load, and load carrying capacity of the masonry construction. Since masonry is usually used as an exposed material it is subjected to tighter dimensional tolerances than those for structural frames. The tolerances given are based on structural performance, not aesthetics." Figure 3 schematically shows permissible variations for masonry construction in accordance with ACI 530.1, *Specification for Masonry Structures*. The masonry inspector and contractor can both rely on these tolerances, for structural reasons, to establish acceptability of constructed masonry.



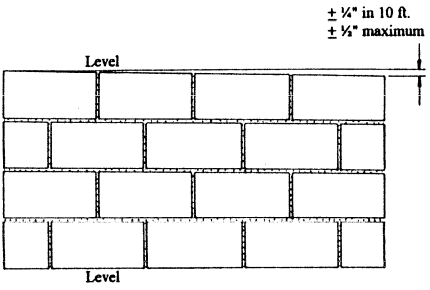
Permissible variation in mortar joint thickness



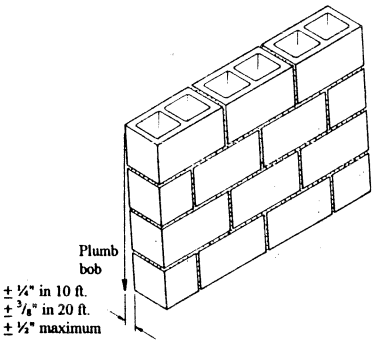
Permissible variation of grout space



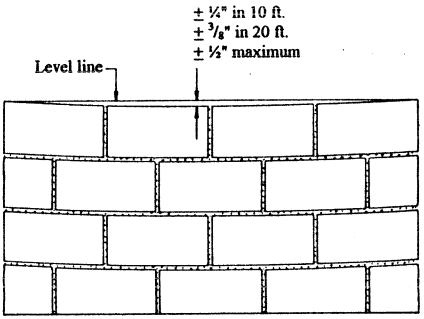
Permissible variation from level for head joints



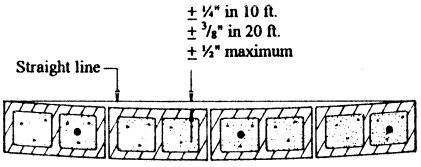
Permissible variation from level, top surface of bearing walls



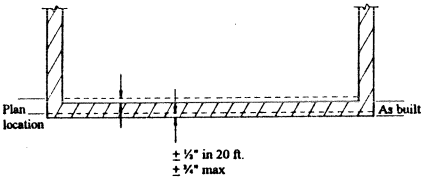
Permissible variation from plumb



Permissible variation from true to line



Permissible variation from true to line



Permissible variation of element indicated in plan

Figure 3 Allowable tolerances in accordance with ACI 530

Frequently, mason contractors make suggestions during the project that will enhance the quality of construction. These suggestions should be seriously considered since construction quality beyond the minimum code requirement level benefits everyone. The Owner benefits from the additional construction quality received, the designer benefits from quality that exceeds the initial expectations and the contractor benefits from a satisfied customer and an installed application that outperforms the minimum Code requirements.

Although the traditional approach for such suggestions is through the general contractor to the Architect and ultimately the Owner, it is not unusual for the masonry inspector to be involved in this information pipeline. As an agent of the Owner, the recommendations of the inspector to accept contractor suggestions will be recognized with merit.

THE RIGHT APPROACH

Most successful projects are successful as a result of teamwork. It is necessary for each team player to understand and respect the duties and responsibilities of the other players. An inspector is often mischaracterized as a project policeman, judge and jury. It is more appropriate to think of the masonry inspector as the quality control representative of the mason contractor. Correct, mason contractor. The seasoned masonry inspector will use his knowledge of the code to actually help the mason contractor. As a team player, the inspector should understand that even the best bricklayers are not perfect, and, as a team player, the bricklayer understands that the masonry inspector is there in the interest of the owner and design professional.

A guideline for the required level of inspection is contained in Tables 1, 2 and 3. This will be contained in the ACI 530-98.

Table 1 is the absolute minimum level of inspection required for any masonry construction. Specifically, Table 1 applies to empirically designed masonry, glass unit masonry and masonry veneer for non-essential facilities. For essential facilities, such as hospitals and emergency shelters, designed empirically, glass unit masonry and masonry veneer, the inspection requirements of Table 2 shall apply.

For all other masonry, the inspection provisions of Table 2 apply for non-essential facilities and the inspection provisions of Table 3 apply for essential facilities. See Figure 4 for a schematic clarification of the inspection requirements.

The guidelines drafted and presented in Tables 1, 2 and 3 require less inspection of masonry than presently exists under the Uniform Building Code. Conversely, the tables outline more masonry inspection requirements for those presently under the jurisdiction of ACI 530. This represents a compromise in the unification process for the single model code that is to be implemented in the United States. It is conceivable that certain West Coast regions, particularly, Washington and California, may not relax the current continuous masonry inspection requirements contained in the Uniform Building Code.

TABLE 1-Level 1 Quality Assurance

MINIMUM TEST AND SUBMITTALS	MINIMUM INSPECTION
Certificates for materials used in masonry construction indicating compliance with contract documents.	Verify compliance with the approved submittals

TABLE 2-Level 2 Quality Assurance	
MINIMUM TEST AND SUBMITTALS	MINIMUM INSPECTION
Certificates for materials used in masonry construction indicating compliance with contract documents Verification of f'_m prior to construction, except where specifically exempted by this Code	As masonry construction begins, verify the following are in compliance: • proportions of site prepared mortar • construction of mortar joints • location of reinforcement and connectors Prior to grouting, verify the following are in compliance: • grout space • placement of reinforcement and connectors • proportions of site prepared grout • construction of mortar joints Verify grout placement is in compliance Observe preparation of grout specimens, mortar specimens and/or prisms Verify compliance with the required inspection provisions of the contract documents and the approved submittals

TABLE 3-Level 3 Quality Assurance	
MINIMUM TEST AND SUBMITTALS	MINIMUM INSPECTION
Certificates for materials used in masonry construction indicating compliance with contract documents Verification of f'_m • prior to construction • every 5,000 sq. ft. during construction Verification of proportions of materials in mortar and grout as delivered to the site	From the beginning of masonry construction and continuously during construction of masonry, verify the following are in compliance: • preparations of site mixed mortar and grout • placing of masonry units and construction of mortar joints • placement of reinforcement and connectors • grout space prior to grouting • placement of grout Observe preparation of grout specimens, mortar specimens, and/or prisms Verify compliance with the required inspection provisions of the contract documents and the approved submittals

In order to determine the type of inspection required, it is necessary to define what is considered an essential facility. According to ASCE 7-95, essential facilities are:

- Hospitals and other health care facilities having surgery or other emergency treatment facilities
- Fire, rescue and police stations and emergency vehicle garages
- Designated earthquake, hurricane or other emergency shelters
- Communication centers and other facilities required for emergency response
- Power generating stations and other public utility facilities required in an emergency
- Buildings and other structures having critical national defense functions

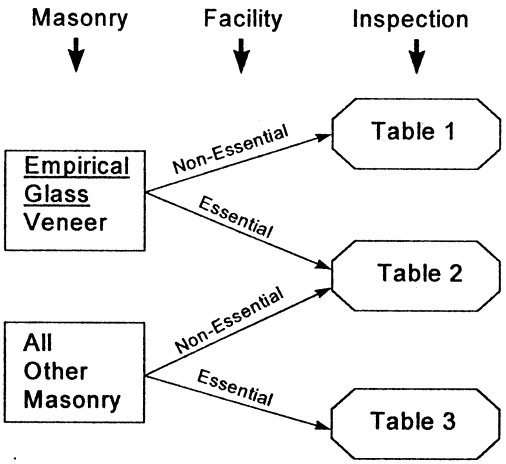


Figure 4 Inspection table flow chart

CONCLUSION

Any code that assumes masonry is inspected is dangerous. An objective observation to assure that the hidden structural elements, such as grouted reinforcement, must be performed by a neutral party in a manner that will not bias his or her performance. The only effective approach is for the inspector to be responsible to the owner.

As an independent observer, the inspector can be the catalyst in the construction process that will give engineer and the architect satisfaction that their design has been implemented and give the building owner and user assurance that the building will perform as intended.

References

American Society for Testing Materials (1996) C 90, Standard Specification for Loadbearing Concrete masonry Units

Amrhein, J, E. and Chrysler, J., (1995) "Reinforced Concrete Masonry Construction Inspector's Handbook", 3rd Edition, Masonry Institute of America, Los Angeles

Building Code Requirements for Masonry Structures (ACI 530-95/ASCE 5-95/TMS 402-95), American Concrete Institute, Detroit, Michigan, American Society of Civil Engineers, New York, N. Y., The Masonry Society, Boulder, Colorado

Building Code Requirements for Concrete Masonry Structures (ACI 531-79), American Concrete Institute, Detroit, Michigan

Chrysler, J. and Amrhein, J., (1996) "Special Masonry Inspection: The Inspector", Proceedings of the 7th North American Masonry Conference, Notre Dame, Indiana, The Masonry Society

Minimum Design Loads for Buildings and Other Structures (ASCE 7-95), American Society of Civil Engineers, New York, N. Y.

Specifications for Masonry Structures (ACI 530.1-95/ASCE 6-95/TMS 602-95), American Concrete Institute, Detroit, Michigan, American Society of Civil Engineers, New York, N. Y., The Masonry Society, Boulder, Colorado

Uniform Building Code, (1997), Chapter 21, Masonry

Uniform Building Code, (1997) Chapter 17, Structural Tests and Inspections

Uniform Building Code, (1997) Standard 21-4, Hollow and Solid Load-Bearing Concrete Masonry Units