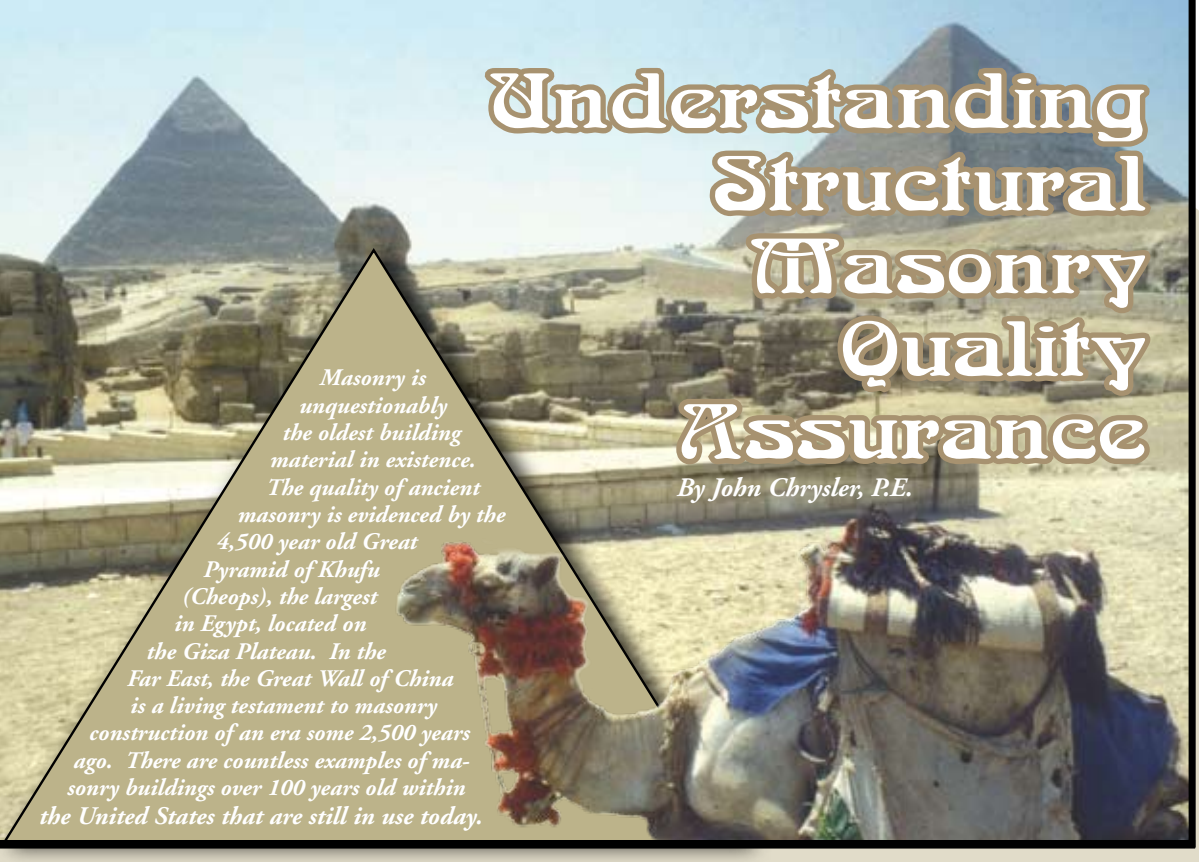
Understanding Structural Masonry Quality Assurance

By John Chrysler, P.E.



Masonry is unquestionably the oldest building material in existence. The quality of ancient masonry is evidenced by the 4,500 year old Great Pyramid of Khufu (Cheops), the largest in Egypt, located on the Giza Plateau. In the Far East, the Great Wall of China is a living testament to masonry construction of an era some 2,500 years ago. There are countless examples of masonry buildings over 100 years old within the United States that are still in use today.

These structures were not simply put on a fast-track method of construction. The designers, builders and material suppliers associated with the project took the time to include quality in the development and construction process. By doing this, the rewards of a functional and aesthetically attractive structure last for generations.

There are a few simple fundamentals to consider in the application of quality assurance for masonry construction. The first basic concept is to understand the materials used in masonry. Additionally, the performance of the structural components, particularly reinforcement and grout, are essential to the durability of masonry. Communication among those associated with the design and construction process has a significant impact on the attitude contributing to design and construction quality.

Understanding the Materials

Concrete design and construction is prevalent throughout the United States. As a result, many associate any cement-based product, such as masonry, with concrete. While there are many similarities, there are some noteworthy differences.

The material most misunderstood is grout. There are two major differences between grout and concrete. First, the grout must be fluid enough to be placed in the confines of a masonry wall, and second, the coarse aggregate for masonry grout is pea gravel, typically not exceeding ⅜ inch (9.5 mm) in size.

Masonry grout must be fluid, but not to the point where there is segregation of the materials. Historically, the fluidity of grout has been obtained by a sufficient content of water. *Specification for Masonry Structures* (ACI 530.1-05/ASCE 5-05/TMS 602-05 Article 2.6 B.2), defines an 8 to 11 inch (203 to 279 mm) slump as adequately fluid for grout. This slump range can be achieved by water or by plasticizers. With such high water content, one might conclude that the masonry grout will not achieve adequate strength. Two factors must be considered.

First, the fluidity is essential for grout to flow both vertically and horizontally in the wall and around obstructions such as reinforcing steel, electrical and plumbing conduits, anchor bolts and other embedments. Grout that is not sufficiently fluid will congest in the restricted areas causing voids in the masonry wall. Second, the excess water is immediately absorbed by the masonry units reducing the grout water content significantly. Evidence of this is shown when the water bleeds to the exposed surface of the masonry unit. Once the excess water is absorbed by the units, the grout begins to hydrate in a normal manner.

The aggregate size for masonry grout is limited by ASTM C 404, *Standard Specification for Aggregate for Masonry Grout, Table 1*. At least 85% coarse aggregate must pass the 9.5 mm (⅜ inch) sieve and 100%

Table 1: Quality Assurance/Inspection Level Required by IBC 1704.5

Masonry Type	Building Type/Use	
	Non Essential Facility	Essential Facility
Empirical Masonry Glass Block Masonry Masonry Veneer	Exempt (IBC Section 1704.5.1)	Level 1 (IBC Tables 1704.5.1 & 1708.1.2)
Masonry designed by Strength Design or Allowable Stress Design	Level 1 (IBC Tables 1704.5.1 & 1708.1.2)	Level 2 (IBC Tables 104.5.3 & 1708.1.4)

of the coarse aggregate must pass the 12.5 mm (½ inch) sieve. Larger aggregate is not permitted in masonry grout. This restriction allows grout to pass around obstructions such as reinforcing steel, pipes and conduits often present within a masonry wall.

A masonry wall is assembled using masonry units and mortar. In addition, many walls incorporate either deformed or joint reinforcement, and walls using deformed reinforcement must be grouted. These multiple components are assumed to contribute to a homogeneous system, and appropriate factors of safety are incorporated to justify this assumption.

Assembling the masonry units with mortar is straightforward. Post-construction analysis of masonry units and mortar is possible since both of the components are exposed. The grout and reinforcement are not exposed; therefore, proper materials and construction are essential for long-term structural performance.

Inspection Requirements

Section 204 of the 1943 *Uniform Building Code* contained the first provision for masonry inspection. This provision required full-time masonry inspection when masonry stresses exceeded 50% of stresses allowed in the masonry design chapter.

Since then, inspection has evolved into a defined profession, where the special masonry inspector focuses on the structural aspects of masonry for the benefit of the design professional and developer. Currently, salient tasks of masonry inspection are listed in Tables 1704.5.1 and 1704.5.3 of the *International Building Code* (IBC) based on the design and service demand of the masonry.

Naturally, empirically-designed masonry walls of a strip mall would not require the same level of inspection as a hospital subjected to seismic or high wind loads. The installation quality should not be inferior for non-continuous inspected work, but it is simply not verified. The level of inspection required for the building type/use is given in *Table 1*.

Tables 2 and *3* detail the requirements for Minimum Tests and Submittals and Minimum Inspection Requirements based on the *International Building Code*. These tasks are specific and when the designer is familiar with the tasks, they are aware of the independent structural verification. When the designer requires additional inspection tasks, the requirements must be clearly conveyed in the project documents.

The most significant difference in the two tables is that Level 2 Quality Assurance requires more continuous inspection. This is reasonable, since Level 2 applies to essential facilities that are designed by Allowable Stress or Strength Design.

The most important task of the structural masonry inspector is to see that the reinforcement is properly placed and grouted. This verifies that the masonry system is constructed in accordance with the professional design.

Table 2: Level 1 Quality Assurance/Inspection[1]

Minimum Tests and Submittals	Minimum Inspection
	Activities Requiring Continuous Inspection Tasks:
Certificates of compliance of materials used in masonry construction.[2]	• Welding reinforcing bars • Grout placement[2] • Grouting of prestressing bonded tendons[2] • Preparation of test specimens[2]
Verification of *f'm* prior to construction, except where specifically exempted by the code.[2]	**Items of Periodic Inspection Tasks:** ***Verify the Following:*** ***As Masonry construction begins, compliance of:***
	• Proportions of site prepared mortar[2] • Construction of mortar joints[2] • Location of reinforcement/connectors[2] • Prestressing technique[2] • Grade/size of prestressing tendons/anchorages[2]
	During Construction:
	• Size/location of structural elements • Type/size/location of anchors[2] • Size/grade of reinforcement[2] • Protection in hot/cold weather conditions • Application/measurement of prestressing force
	Prior to grouting:
	• Clean grout space[2] • Placement of reinforcement/connectors, prestressing tendons/anchorages[2] • Proportions of site-prepared grout/prestress grout[2] • Construction of mortar joints[2]

[1] Based on IBC Table 1704.5.1
[2] Corresponding provisions contained in Building Code Requirements for Masonry Structures, Table 1.15.2 and Specification for Masonry Structures, Table 4

Structural Inspection

The International Code Council (ICC) issues certificates titled "Structural Masonry Special Inspector" to those individuals successfully completing the examination for the discipline. The paramount duty of the Structural Masonry Special Inspector is to observe the progression of masonry installation and note any discrepancies with the plans, specifications, or governing building code. This procedure is meant to assure that the work constructed conforms to the intent of the design.

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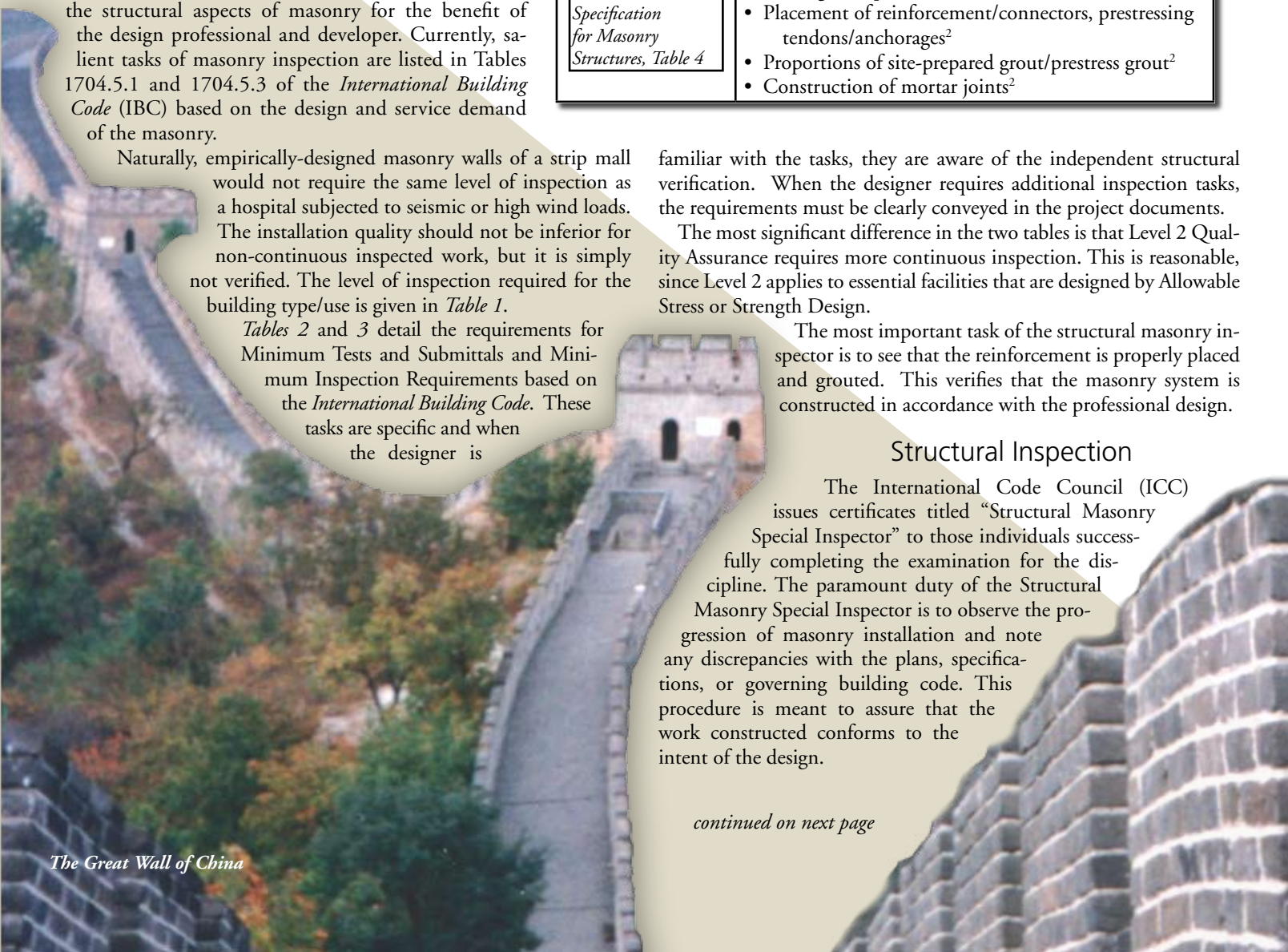

The Great Wall of China

Table 3 - Level 2 Quality Assurance/Inspection[1]

Minimum Tests and Submittals	Minimum Inspection
	Activities Requiring Continuous Inspection Tasks: ***Verify the following: From the very beginning of masonry construction***
Certificates of compliance of materials used in masonry construction.[2]	• Grout space prior to grouting [2] • Placement of grout [2] • Placement of prestressing grout [2]
Verification of *f'm:* • prior to construction[2] • every 5,000 square feet during construction[2]	***During Construction*** • Type/size/location of anchors [2] • Welding of reinforcement • Application/measurement of prestressing force • Preparation of test specimens [2]
Verification of proportions of materials in mortar and grout delivered to the site.[2]	**Items Requiring Periodic Inspection Tasks:** ***Verify the following: As masonry construction begins compliance of:*** • Proportions of site-prepared mortar/grout/prestress grout[2] • Placement of masonry units[2] • Construction of mortar joints[2] • Placement of reinforcement/ connectors/prestressing tendons/ anchors[2]
	During Construction • Size/location of structural elements • Size/grade/type of reinforcement[2] • Protection in hot/cold weather conditions

[1] *Based on IBC Table 1704.5.3*
[2] *Corresponding provisions contained in Building Code Requirements for Masonry Structures, Table 1.15.3 and Specification for Masonry Structures, Table 5*

The use of the structure dictates the amount of inspection. Naturally, the designer may require additional inspection, particularly if the work is difficult or the building must be operational after a disaster.

One misconception is that using a Masonry Special Inspector on the project will prohibitively increase construction cost. Often, the Masonry Special Inspector will draw attention and cause correction of construction discrepancies. Without Special Masonry Inspection, designers would likely increase structural requirements, causing increases in material and construction costs.

Non-Structural Inspection

Certain types of masonry construction should be independently observed for performance reasons. For example, an unreinforced, ungrouted masonry wall will typically contain through-wall flashing at the base of the wall for moisture drainage to the building exterior. The designer may require independent observation of the installation of this element to assure the proper performance over the life of the masonry wall.

Independent observation of overhead signage into masonry walls would follow the intent of the building code. Connection failure could lead to catastrophic results.

Communication

Successful masonry construction requires teamwork. Too often, communication is not considered an important element of the construction process. The designer must convey a clear message to the field personnel of what the intended final product should be, and the field personnel must ask questions when they are uncertain of the intent of the project documents.

Responsibility for applying the building code to the construction process lies with the building official. The special inspector can be considered an extension of the building official. The special inspection concept has been set up so that the two work together in order to achieve a structurally safe building that conforms to the minimum requirements of the building code as well as the project documents. The special inspector should communicate with the building official at the start of masonry work and let the building official know the scope of the work (masonry) to satisfy IBC Section 104.4.

The general responsibilities of parties involved in construction are listed in the *Table 4*.

Conclusion

Quality masonry construction can be delivered, but it takes the cooperation of all parties. Like concrete, masonry can be reinforced and grouted to withstand the most severe lateral forces, but unlike concrete, the materials must be placed with different means and methods for an effective structural system.

As issues that have structural implications arise during construction, the designer must be aware of the unique nature of masonry in design and construction. Such an understanding will aid in delivering a quality masonry project to the end user. ▪

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Table 4: Project Responsibility Summary

Party	Responsibility
Design Professional	Produce project documents that satisfy the intent and needs of the end user.
Building Official	Ensure that the requirements of the general building code are met.
Special Masonry Inspector	Observe construction of masonry work and monitor test procedures as required by the code and contract documents.
General Contractor	Coordinate overall construction of the project. Contact point for all associated with the project.
Masonry Contractor	Construction of the masonry work.
Masonry Material Supplier	Provide materials certified to conform to the required material standards