

## Masonry Materials: A Technical Overview Based on the Latest TMS Code

### INTRODUCTION:

---

Masonry is a construction technique that involves bonding individual units—such as bricks, stones, concrete blocks, or glass blocks—with mortar to create structural elements. It is widely used for both load-bearing and non-load-bearing applications due to its durability, fire resistance, and thermal performance. The selection of masonry materials significantly impacts structural integrity, longevity, and energy efficiency. The *TMS 402/602-22 Building Code Requirements and Specification for Masonry Structures* offers comprehensive guidelines on material selection, unit strength, mortar properties, and reinforcement detailing. This article provides an in-depth analysis of masonry materials, their mechanical properties, and the latest design provisions to ensure compliance with modern structural standards.

### COMMON MASONRY PATTERNS

---

Most brick bonds require bricks (or other masonry units) of the same size or at least compatible sizes. Uniform sizing creates a regular, repeatable pattern that can be applied over any size of the area. Many bond patterns include some method of interlocking each row of brick (called a course) to the neighboring courses by providing strength to the construction. Several masonry patterns are used in construction, each with distinct aesthetic and structural characteristics as shown and further explained in Figure 1:

**BRICKS:** Bricks are one of the most traditional masonry units, typically made from clay and subjected to high-temperature firing. They come in various types:

- Common Bricks: Used for general construction, these bricks have moderate strength and are often covered with plaster or other finishes.
- Facing Bricks: Manufactured for aesthetic appeal with uniform color and texture, commonly used in facades.
- Engineering Bricks: Designed for high strength and low water absorption, making them suitable for damp-proof courses and structural applications. The manufacturing process involves molding, drying, and firing at high temperatures, resulting in different levels of hardness and porosity.



Figure 1. Bricks

**CONCRETE MASONRY UNITS (CMUs):** CMUs are the most commonly used structural masonry units and are composed of cement, aggregate, and water, offering a high-strength, durable alternative to bricks. They come in standard sizes such as 8x8x16 inches and are used in structural and non-structural applications. CMUs provide excellent fire resistance and can be reinforced with steel for enhanced load-bearing capacity. TMS 402-22 emphasizes density-based classification for CMUs, which affects thermal properties and weight. Their density, compressive strength, and moisture absorption properties directly influence their application. CMU can be specified as normal weight, medium weight or light weight. The most common CMU is normal weight, yet both medium weight and light weight can also be specified and used. Light weight CMU is recommended for seismic zones due to lower inertia and reduced seismic forces. Normal-weight CMUs are preferred for high-wind zones due to increased resistance to lateral forces. The common compressive strength for CMU,  $f'_{cmu}$  as determined by ASTM C90 tests, is 3250 psi or higher. Higher compressive strength CMU (>3,500 psi) is allowed with modifications in mortar joint detailing and can also be specified if desirable for a particular application, although cost and availability should be determined prior to specifying these higher values.



Figure 2. Concrete Masonry Units

**CALCIUM SILICATE UNITS:** Calcium silicate units are masonry units made from a mixture of sand, lime (calcium oxide), and water, which are then cured under high-pressure steam in an autoclave. This process forms a durable, strong material with excellent dimensional stability.



Figure 3. Calcium Silicate Units

**AUTOCLAVED AERATED CONCRETE (AAC):** Autoclaved Aerated Concrete (AAC) is a lightweight, precast building material made from cement, lime, sand (or fly ash), water, and an expanding agent (typically aluminum powder). The mixture undergoes a high-pressure steam curing process in an autoclave, resulting in a porous, aerated structure that provides excellent thermal insulation and reduced weight. AAC masonry is gaining traction due to its high insulation value and lightweight properties.



Figure 4. Autoclaved Aerated Concrete (AAC)

**NATURAL STONE:** Natural stone is used for both structural and aesthetic purposes. Common varieties include:

- Granite: High durability and resistance to weathering, used for foundations and exterior cladding.
- Limestone: Softer and more workable, used in decorative applications.
- Sandstone: Offers good weather resistance and is often used in heritage buildings.
- Marble: Primarily used for decorative finishes due to its smooth surface and aesthetic appeal. Handling and cutting natural stone require specialized tools and techniques,
- making it a more labor-intensive material.



Figure 5. Natural Stone

**NATURAL STONE:** Glass blocks are translucent masonry units used for aesthetic and lighting purposes in walls and partitions. They provide good thermal insulation and impact resistance but require specialized jointing techniques for stability.



Figure 6. Glass Blocks

Table 1 provides the governing ASTM Specifications as well as minimum strength requirements for different types of masonry units per TMS 402/602-22.

Table 1. Masonry Type Properties

Masonry Type	ASTM Specification	Compressive Strength (psi)	Density Class (pcf)
Concrete Masonry Units (CMU)	ASTM C90	3,250 average	Lightweight (<105), Medium (105-125), Normal (>125)
Clay Brick	ASTM C216	Varies (typically >3,000)	N/A
Calcium Silicate Units	ASTM C73	3,500 min	N/A
Autoclaved Aerated Concrete (AAC)	ASTM C1693	290-1,015	20-50
Natural Stone	Granite – ASTM C615 Limestone – ASTM C568 Sandstone – ASTM C616 Marble – ASTM C503	Granite – 19,000-30,000 Limestone – 1,800-8,000 Sandstone – 4,000-20,000 Marble – 7,000-21,000	Granite – 160-180 Limestone – 120-170 Sandstone – 130-165 Marble – 140-175
Glass Blocks	ASTM C1372	1,500-3,000	120-140

## MORTAR (ASTM C270) and GROUT (ASTM C476) COMPOSITION

Mortar binds masonry units together and affects the overall strength and durability of the structure. Mortar and grout are critical for masonry bond strength and structural integrity. Mortar is a mixture of cementitious material, sand, water, and sometimes lime. The typical composition includes:

- Cement (Portland cement or masonry cement) – Provides strength and bonding. Portland cement is commonly used for general-purpose mortar, offering high strength. Masonry cement contains additional plasticizers to improve workability and flexibility.
- Lime (optional) – Enhances workability, water retention, and flexibility.
- Sand – Acts as an aggregate, providing volume and bonding and preventing excessive shrinkage.
- Water – Activates the cement and facilitates workability preventing excessive shrinkage and cracking upon drying.
- Admixtures (optional) – Including retarders, plasticizers, waterproofing agents. Used to modify properties like setting time, durability, or water retention.

The proportion of these components varies depending on the mortar type (M, S, N, or O), with higher cement content increasing strength and durability. Mortar types vary in compressive strength and application. The choice of mortar significantly affects  $F'm$ . Mortar strength isn't determined solely by mortar-only compression tests, as these tests don't reflect in-wall performance. Instead, TMS 602 allows mortar to be specified using a proportion or property method. Type M, with a minimum strength of 2,500 psi at 28 days, is used for high-load and severe weather conditions, such as retaining walls. Type S, at 1,800 psi minimum, is suitable for structural masonry and seismic regions. Type N, with a 750 psi minimum strength, serves general-purpose above-grade walls. Type O, the weakest at 350 psi, is used for non-load-bearing interior applications. TMS 402-22 emphasizes mortar selection for seismic applications, with Type S preferred for lateral resistance and requires pre-blended mortar testing to ensure quality control. Type S and Type N are the most common mortars, with Type S preferred for structural masonry due to its higher strength and durability.

Grout is used to fill masonry cores, enhancing reinforcement bonding and overall structural integrity. Both fine and coarse grout require a minimum compressive strength of 2,000 psi and a slump of 8 to 11 inches. Thus, grout compressive strength ( $f'g$ ) must meet or exceed  $F'm$  but be no less than 2,000 psi. Though higher grout strengths can improve block/grout compatibility, they don't increase the overall masonry design strength. Updates in TMS 602-22 now allow higher-strength grout formulations to align with high-performance concrete masonry units (CMUs). Additionally, revised slump control recommendations aim to prevent segregation in high-lift grouting, ensuring better consistency and performance.



Figure 7. Mortar and Grout

## REINFORCEMENT and SEISMIC DESIGN CONSIDERATIONS

---

Reinforcement plays a crucial role in masonry construction by enhancing ductility and flexural strength, particularly in structures subject to seismic forces. Masonry itself has high compressive strength but is relatively weak in tension, making reinforcement essential for improving its overall performance under lateral and flexural loads. In seismic applications, properly detailed reinforcement helps dissipate energy, reduce cracking, and prevent structural failure during an earthquake.

Reinforcing steel used in masonry construction must comply with ASTM A615 or A706 standards. Grade 60 reinforcement, with a yield strength of 60 ksi, is the most commonly used and is suitable for standard applications. Grade 80 reinforcement, with a higher yield strength of 80 ksi, provides greater resistance to loads but requires modified lap splicing techniques to ensure structural integrity. A706 reinforcement, designated specifically for seismic applications, also has a yield strength of 60 ksi but offers improved ductility and weldability, making it the preferred choice in high-seismic regions. Common reinforcement techniques include grouted reinforcement within CMU cores and steel ties in brick walls.

The latest updates in TMS 402-22 now allow the use of Grade 80 reinforcement with longer development lengths, addressing the need for higher-strength reinforcement while maintaining adequate bonding and anchorage. These changes provide engineers with more flexibility in selecting reinforcement while ensuring structural safety.

Seismic design considerations for reinforced masonry structures vary depending on the seismic hazard level, classified into Seismic Design Categories (SDC). Vertical reinforcement and horizontal bond beam spacing are key factors in designing masonry structures to withstand seismic loads. In low seismic zones (SDC A, B), where earthquake forces are minimal, vertical reinforcement typically consists of #5 bars spaced at 48 inches on center, with horizontal bond beams placed at 72 inches on center. In moderate seismic zones (SDC C), where greater lateral forces are expected, vertical reinforcement is tightened to #5 bars at 32 inches on center, and bond beams are placed at 48 inches on center to improve the structure's ability to resist seismic movements. For high seismic zones (SDC D, E, F), which experience the most significant earthquake forces, vertical reinforcement is further increased to #5 bars at 24 inches on center, and bond beams are spaced 36 inches on center to enhance lateral load resistance and improve ductility.

Recent updates in TMS 402-22 also introduce refinements to lap splice requirements for ductile walls, ensuring that spliced reinforcement maintains sufficient strength and continuity under seismic loading. Additionally, shear wall confinement requirements have been strengthened, increasing the robustness of masonry walls to resist in-plane shear forces. These improvements collectively contribute to safer, more resilient masonry structures in seismic-prone areas.

## INNOVATIONS IN MASONRY MATERIALS

---

Recent advancements in masonry materials focus on improving strength, durability, thermal efficiency, and sustainability. Innovations such as lightweight concrete blocks, fiber-reinforced bricks, and self-healing mortars are revolutionizing the industry, offering enhanced performance and environmental benefits.

**LIGHTWEIGHT CONCRETE BLOCKS:** Lightweight concrete masonry units (CMUs) incorporate materials such as expanded clay, shale, or perlite to reduce density without compromising strength. These blocks provide better thermal insulation, lower dead loads, and easier handling, making construction more efficient. Their reduced weight also decreases the structural demand on foundations and enhances seismic performance.

**FIBER-REINFORCED BRICKS:** Traditional bricks are being enhanced with polypropylene, glass, or carbon fibers to improve tensile strength, crack resistance, and durability. Fiber reinforcement reduces shrinkage cracking, enhances impact resistance, and increases energy absorption in seismic applications. These bricks are especially beneficial in areas prone to earthquakes and extreme weather conditions.

**SELF-HEALING MORTARS:** Self-healing mortars use bacteria-based or microcapsule technology to repair minor cracks autonomously. Bacteria-based mortars contain spores that activate when water enters a crack, precipitating calcium carbonate (CaCO<sub>3</sub>) to seal the gap. Microcapsule-based mortars contain healing agents that release upon cracking, forming a new bond. These technologies extend the lifespan of masonry structures, reducing maintenance costs and increasing sustainability.

**3D-PRINTED MASONRY COMPONENTS:** Advances in additive manufacturing (3D printing) allow for custom masonry components with optimized shapes and reduced material waste. These components can be produced using sustainable binders and are gaining traction in architectural and structural applications.

## CONCLUSION

---

The evolution of masonry materials and design practices, guided by the latest **TMS 402/602-22** code, ensures improved structural performance, safety, and sustainability. The selection of masonry units, including bricks, concrete blocks, plays a critical role in determining a structure's durability and efficiency. Advances in **mortar and grout formulations**, alongside **reinforcement strategies**, contribute to stronger, more resilient masonry systems, particularly in seismic applications.

Further, innovations such as **lightweight masonry, self-healing mortars, and 3D-printed components** are shaping the future of masonry construction, offering enhanced performance while addressing sustainability concerns. The **recent updates in seismic detailing, reinforcement requirements, and material selection** provide engineers with greater flexibility and efficiency in designing modern masonry structures. By integrating these advancements, masonry construction continues to adapt to evolving industry demands, ensuring safer and more efficient buildings for the future.