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SURFACE BONDED CONCRETE MASONRY CONSTRUCTION

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INTRODUCTION

Surface bonding is an economical construction technique which was first introduced in the late sixties by the U. S. Department of Agriculture for use in low cost housing. In surface bonded construction, concrete masonry units are laid dry and stacked, without mortar, to form walls. Walls are constructed with units that have been precision ground or honed to achieve a uniform bearing surface, or with shims placed periodically to maintain a level and plumb condition. Both sides of the wall are then coated with a thin layer of reinforced surface bonding mortar. The synthetic fibers which reinforce the surface bonding mortar impart a tensile strength of about 1500 psi (10.3 MPa), producing a strong wall despite the relatively thin thickness of material on each side. The surface coating on each side of the wall bonds the concrete masonry units together in a strong composite construction, and serves as a protective water resistant shield.

Surface bonded concrete masonry has a number of advantages:

- Less time and skill are required for wall construction. In a 1972 study of mason productivity sponsored by the U. S. Department of Housing and Urban Development and other interested organizations, it was found that surface bonded concrete masonry construction resulted in 70 percent greater productivity than that achievable with conventional construction.
- The surface bonding mortar provides excellent resistance to water penetration in addition to its function of holding the units together. Tests of surface bonded walls have repeatedly shown their resistance to wind driven rain to be "excellent" even with wind velocities as great as 100 mph (161 km/h), and over test periods of 8 hours.
- Colored pigment can be incorporated into the surface bonding mortar to produce a finished surface without the need to paint.

Surface bonded concrete masonry construction offers all of the benefits and advantages of conventional concrete masonry construction, such as:

- fire safety
- acoustic insulation
- energy efficiency
- lasting durability and beauty

DESIGN STRENGTH

Many structural and nonstructural tests have been performed on surface bonded walls to establish design parameters for the system.

The nonstructural properties, such as sound transmission class, fire resistance period, and energy efficiency, of surface bonded concrete masonry can be considered equivalent to a conventional mortared concrete masonry wall.

There are a few differences between the structural properties of the two types of construction. These differences are discussed in the following paragraphs, and are illustrated in

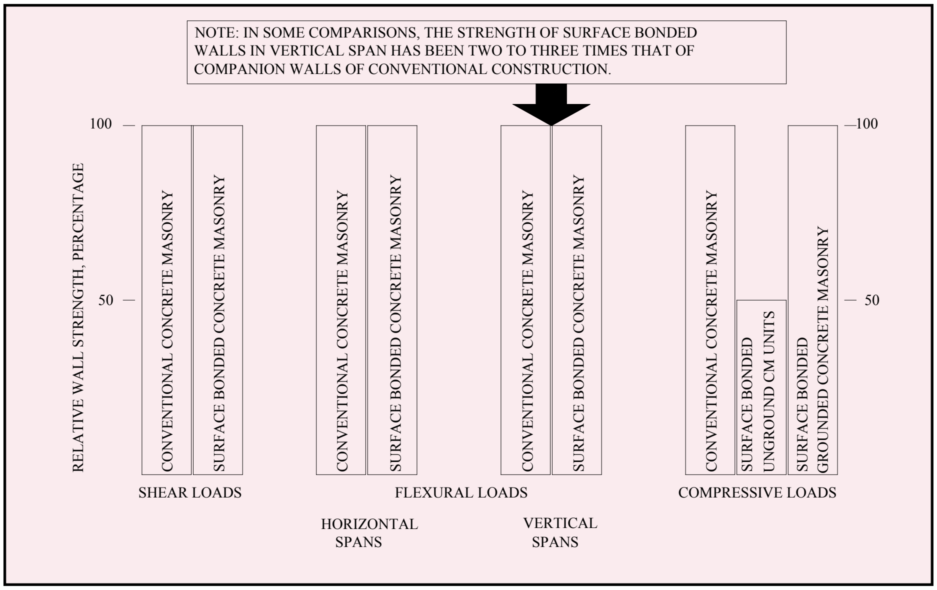

Figure 1 for ungrouted, unreinforced walls. Although national building codes, such as the *BOCA National Building Code* and the *Standard Building Code* (refs. 1, 3) do not specifically address reinforced or grouted surface bonded walls, manufacturers of surface bonding mortars may have code-approved criteria for their products.

Compressive Loads

Resistance to vertical compressive loads depends primarily on the compressive strength of the concrete block used in the wall construction. Stronger units make stronger walls. With mortared construction, a rule of thumb is that the wall strength will generally be about seventy percent of the unit strength. In comparison, surface bonded walls built with unground concrete masonry units develop approximately thirty percent of the strength of the individual block. This reduced wall strength is depicted in Figure 1 for walls constructed with unground concrete masonry units.

The lower value obtained with the unground units is due to a lack of solid bearing contact between units, due to the natural roughness of the concrete units. The mortar bed used in conventional construction compensates for this roughness and provides a uniform bearing between units. If the masonry unit bearing surfaces are ground flat and smooth before the wall is erected, results similar to those for a mortared wall can be expected. In Figure 1, note that surface bonded walls built with precision ground concrete masonry units are equally as strong in compression as the conventional construction.

Flexural Resistance

The flexural strength of a surface bonded wall is about the same as that of a conventional mortared wall, as shown in Figure 1. When walls are tested in the vertical span (i.e., a horizontal force, such as wind, is applied to a wall that is supported at the top and bottom) surfaced bonded walls and mortared walls have about the same average strength; failure occurs in the surface bonded coating due to tensile stress at or near one of the horizontal joints. With mortared construction, failure occurs at a horizontal joint with bond failure between the mortar and the masonry units. The data from numerous tests on surface bonded constructions led to an allowable stress of 18 psi (0.12 MPa) based on the gross area.

When walls are laid in a running bond pattern, either with mortar joints or with surface bonding, and tested in the horizontal span, (i.e., a wall supported at each end is subjected to a horizontal wind force) the strength in bending depends primarily on the strength of the units. This is due to the interlocking of the masonry units laid when in a running bond configuration. In such tests in the horizontal span, the wall strength of the surface bonded wall is exactly the same as the conventional construction. In Table 1, an allowable flexural stress of 30 psi (0.21 MPa) is recommended for horizontal span when the units have been laid in running bond.

Shear Strength

The shear resistance of surface bonded construction is the same as that of conventional walls. With face shell mortar bedding, conventional concrete masonry walls averaged 42 psi (0.29 MPa) shear resistance, based on gross area. Nine surface bonded walls, 8 in. (203 mm) in thickness, had an average shear resistance of 39 psi (0.27 MPa), and three 6 in. (152 mm) thick surface bonded walls averaged 40 psi (0.28 MPa). These data are compared in Figure 1, and led to a recommended allowable shear stress of 10 psi (0.07 MPa) on the gross area (see Table 1).

Table 1—Allowable Stress, Gross Cross-Sectional Area, Dry-Stacked, Surface-Bonded Concrete Masonry Walls[a]

Compression:	45 psi (0.31 MPa)
Shear:	10 psi (0.07 MPa)
Flexural Tension:	*Horizontal span*: 30 psi (0.21 MPa) *Vertical span:* 18 psi (0.12 MPa)

[a] References 1 & 3

CONSTRUCTION

The construction procedure for surface bonded walls is similar to that of conventional, except that mortar is not placed between the masonry units. *Standard Practice for Construction of Dry-Stacked, Surface-Bonded Walls*, ASTM C 946 (ref. 4), governs the construction methods. Care should be taken to ensure uncoated walls are adequately braced.

Because the walls are constructed without mortar joints, surface bonded wall dimensions do not conform to the standard 4 in. (102 mm) design module. Wall and opening dimensions should be based on actual unit dimensions, which are typically $7^5/_8$ in. high by $15^5/_8$ in. long (194 by 397 mm).

Materials

Surface bonding mortar should comply with *Standard Specification for Packaged, Dry, Combined Materials for Surface Bonding Mortar,* ASTM C 887 (ref. 6), which governs flexural and compressive strength, sampling, and testing.

ASTM C 946 requires Type I, moisture-controlled, concrete masonry units be used for surface bonded construction. Type I units must be in a dry condition when delivered to the job site. Walls laid using dry units will undergo less drying shrinkage after construction, hence minimizing cracks. *Standard Specification for Loadbearing Concrete Masonry Units*, ASTM C 90 (ref. 5) governs these requirements.

As for mortared masonry construction, materials should be properly stored on site to prevent contamination by rain, ground water, mud, and other materials likely to cause staining or to have other deleterious effects.

If the bearing surfaces of the concrete masonry units are unground, metal or plastic shims or mortar may occasionally be required between units to maintain the wall level and plumb. Shims must have a minimum compressive strength of 2000 psi (13.8 MPa) to ensure their long term durability after the wall is loaded. Metal shims, if used, should be corrosion resistant to reduce the possibility that they will corrode and bleed through the finished masonry at a later time.

Leveling

Because the footing is not typically level enough to lay up the dry units without additional leveling, the first course of masonry units is laid in a mortar bed or set in the fresh footing concrete to obtain a level base for the remainder of the wall. Vertical head joints should not be mortared, even when the first course is mortar bedded, since mortar in the head joints will misalign the coursing along the wall length.

When required, additional leveling courses are constructed in the wall. Leveling courses should be placed when:

- the wall is out of level by more than 1/2 in. (13 mm) in 10 ft,
- at each floor level, and
- at a horizontal change in wall thickness (see Figure 2).

After the first course of masonry units is laid level in a mortar bed, dry stacking proceeds with the remaining courses beginning with the corners, and followed by stacking, in running bond, between the corners. As they are dry stacked, the ends of the concrete masonry units should be butted together tightly. Small burrs should be removed prior to placement.

After every fourth course, the wall should be checked for plumb and level.

Crack Control

Temperature and moisture movements have the potential to cause small vertical cracks in a masonry wall. These cracks are an aesthetic, rather than a structural, concern. In exposed concrete masonry, where shrinkage cracks may be objectionable, horizontal joint reinforcement, control joints, or bond beams are used to control cracking. The absence of a mortar bed joint in surface bonded walls means that there is no space in the wall for joint reinforcement, so control joints or bond beams are used for crack control.

Control joints should be placed:

1. at wall openings and at changes in wall height and thickness
2. at wall intersections, at pilasters, chases, and recesses
3. in walls without openings, at intervals of 20 ft (6.1 m) when there are no bond beams in the construction, and at intervals of 60 ft (18.3 m) when bond beams are incorporated every 4 ft (1.2 m) vertically.

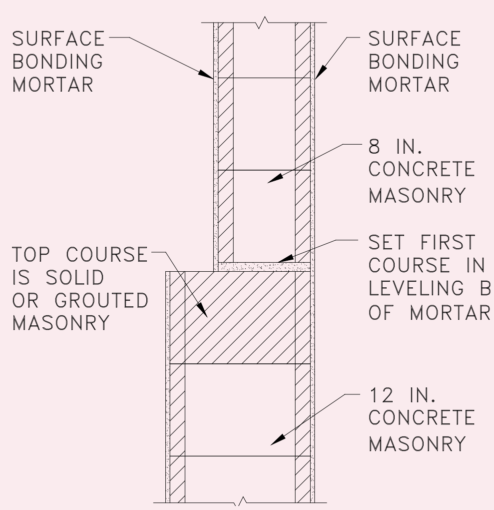

Figure 2—Change in Wall Thickness

Control joints for surface bonded walls are similar to those for mortared concrete masonry. At the control joint location, the surface bonding mortar should be raked out and the joint caulked.

Placing Accessories & Utilities

The absence of a mortar bed joint in the construction also requires that the face shell and/or the cross web of the concrete masonry units be notched or depressed whenever wall ties or anchors must be embedded in the wall. A coarse rasp is typically used to make small notches, while deeper notches are cut with a masonry saw. Cores containing anchors or wall ties should be grouted, or other adequate anchorage should be provided.

Electrical lines and plumbing are often located in the cores of concrete masonry units. These lines should be placed before the surface bonding mortar is applied, so that the masonry units are visible.

Applying Surface Bonding Mortar

Manufacturer's recommendations should be followed for job site mixing of the premixed surface bonding mortar and application to the dry stacked concrete masonry wall.

As with mortared masonry construction, clean water and mixing equipment should be used to prevent foreign materials from being introduced into the mortar. Batches should be mixed in full bag multiples only, to compensate for any segregation of materials within a bag.

All materials should be mixed for 1 to 3 minutes, until the mixture is creamy, smooth, and easy to apply. Note that mixing time should be kept to a minimum, as overmixing can damage the reinforcing fibers.

The stacked concrete masonry units should be clean and free of any foreign matter which would inhibit bonding of the plaster. Contrary to recommended practice with conventional mortared walls, the dry stacked concrete masonry units should be damp when the surface bonding plaster is applied to prevent water loss from the mortar due to suction of the units. Care should be taken to avoid saturating the units.

It is very important that the surface bonding mortar be applied to both sides of the dry stacked wall since the wall strength and stability depend entirely on this coating.

Premixed surface bonding mortars are smooth textured and easily applied by hand with a trowel. The workability is due to the short 1/2 in. (13 mm) glass fibers which reinforce the mixture. The mortar should be troweled on smoothly with a minimum thickness of 1/8 in. (3 mm).

Surface bonding mortar can also be sprayed on. On large projects, use of a power sprayer greatly increases the coverage rate of the mortar and further reduces wall costs. As applied, the "sprayed-on" surface bonding mortar usually has a rougher surface texture than a troweled finish, and possesses slightly less tensile strength due to the lack of fiber orientation in the plane of the mortar coating. This can be overcome by troweling, hand or mechanical, following spray application of the mortar. Hand or mechanical troweling of the sprayed coating also assures that all gaps and crevices are filled.

When a second coat of surface bonding mortar is applied, either by trowel or spray, it should be applied after the first coat is set, but before it is completely hardened or dried out. The second coat may be textured to achieve a variety of finishes.

Joints in surface bonding mortar are weaker than a continuous mortar surface, and, for this reason, should not align with joints between masonry units. If application of the surface bonding mortar is discontinued for more than one hour, the first application should be stopped at least 1¹/₄ in. (32 mm) from the horizontal edge of the concrete masonry unit.

At the foundation, the surface bonding mortar should either form a cove between the wall and the footer or, for a slab on grade, should extend below the masonry onto the slab edge, as shown in Figure 3. These details help prevent water penetration at the wall/footer interface.

Curing

After surface bonding application, the wall must be properly cured by providing sufficient water for full hydration of the mortar, to ensure full strength development. The wall should be dampened with a water mist between 8 and 24 hours after surface bonding mortar application. In addition, the wall should be fog sprayed twice within the first 24 hours, although with pigmented mortar, this may be extended to 48 hours.

The recommendations above may need to be modified for either cold or hot weather conditions. For example, dry, warm, windy weather accelerates the water evaporation from the mortarrequiring more frequent fog spraying.

At the end of the day, tops of walls should be covered to prevent moisture from entering the wall until the top is permanently protected. Typically, a tarp is placed over the wall, extending at least 2 ft (0.6 m) down both sides of the wall, and weighted down with lumber or masonry units.

REFERENCES

1. *BOCA National Building Code.* Country Club Hills, IL: Building Officials and Code Administrators International, Inc. (BOCA), 1996.
2. *Building Code Requirements for Masonry Structures*, ACI 530-95/ASCE 5-95/TMS 402-95. Reported by the Masonry Standards Joint Committee, 1995.
3. *Standard Building Code*. Birmingham, AL: Southern Building Code Congress International, Inc. (SBCCI), 1997.
4. *Standard Practice for Construction for Dry-Stacked, Surface-Bonded Walls*, ASTM C 946-91 (1996)^{e1}. American Society for Testing and Materials, 1996.
5. *Standard Specification for Loadbearing Concrete Masonry Units*, ASTM C 90-97. American Society for Testing and Materials, 1997.

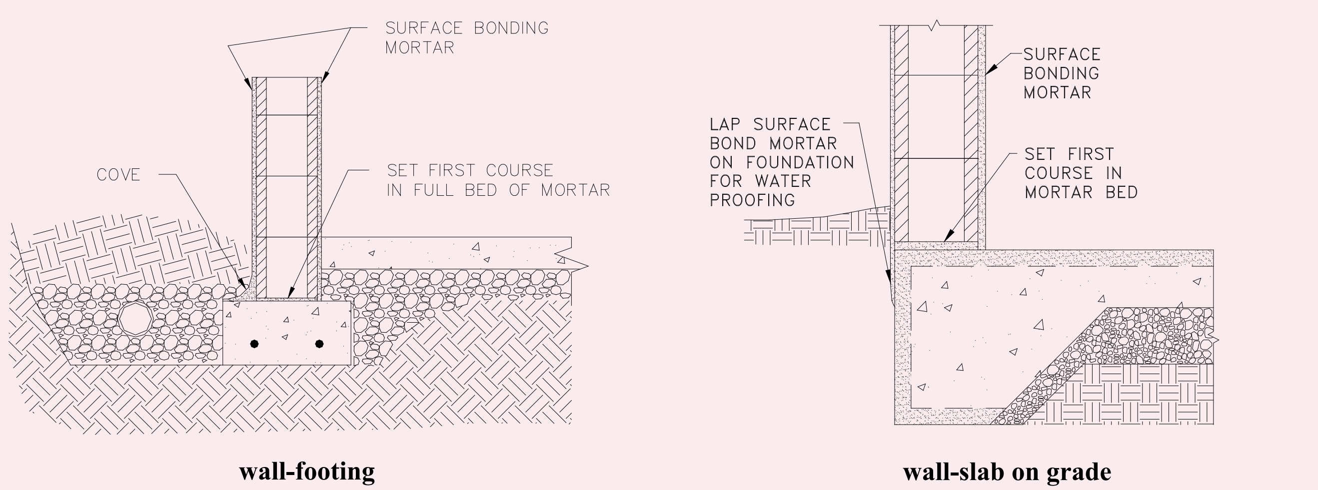

Figure 3—Wall/Footing Interface