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NCMA TEK

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IMPACT RESISTANCE OF CONCRETE MASONRY FOR CORRECTIONAL FACILITIES

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Structural (2003)

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INTRODUCTION

Communities across the nation rely on concrete masonry for their prisons and detention centers. In addition to its strength and durability, the layout of concrete masonry walls and cells can be cost-effectively tailored to meet the facility's needs. Concrete masonry is a proven product for correctional facilities, providing secure construction with a minimum of long-term maintenance.

Concrete masonry walls designed as security barriers are most often fully grouted and reinforced. Typically, vertical grouted cells with steel reinforcing in every cell are provided, although reinforced horizontal bond beams may also be specified. This type of construction is found in prisons, secure facilities or other areas where the integrity of the building envelope or wall partition is vital to secure an area.

Recent testing (refs. 1, 2) confirms the impact resistance of concrete masonry construction, and quantifies the performance of various concrete masonry wall systems.

IMPACT TESTING

Standard Test Methods for Physical Assault on Fixed Barriers for Detention and Correctional Facilities (ref. 3) is being developed to help quantify levels of security for walls designed to incarcerate inmates in detention and correctional institutions. The standard is intended to help ensure that detention security walls perform at or above minimum acceptable levels to: control passage of unauthorized or secure areas, to confine inmates, to delay and frustrate escape attempts and to resist vandalism.

The test method is intended to closely simulate a sustained battering ram style attack, using devices such as benches, bunks or tables. It addresses only those threats which would be anticipated based on the limited weapons, tools and resources available to inmates within detention and correctional facilities.

The draft security wall standard includes provisions to test monolithic wall panels as well as wall panels with simulated window openings. The standard assigns various security grades for fixed barriers based on the wall's ability to withstand the simulated attack (see Table 1).

Attack is simulated via a series of impacts from a pendulum testing ram apparatus. The testing ram is fitted with two heads: a blunt impactor to simulate a sledge hammer, and a sharp impactor simulating a fireman's axe. The testing protocol calls for blows from both the blunt and sharp impactors, applied in sequences of 50 blows each.

Failure of a wall assembly is defined as an opening through the wall which allows a 5 in. x 8 in. x 8 in. (127 x 203 x 203 mm) rigid rectangular box to be passed through the wall with no more than 10 lb (44.5 N) of force.

The draft standard also assigns a representative barrier duration time, based on an historical testing observation that sustained manpower can deliver 400 blows of 200 ft-lb (271.2 J) each in 45 minutes. The element of time assigned to the various security grades

Table 1—Security Grades and Impact Load Requirements (ref. 2)

Grade No.	Number of impacts[a]	Representative barrier duration time, min.
1	600	60
2	400	40
3	200	20
4	100	10

[a] Number of impacts equally divided between blunt impactor (first sequence) and sharp impactor, applied in cyclic sequences of 50 impacts each.

is adjusted to achieve more manageable time periods than actual calculations provide. The amount of time is estimated and is offered solely as supplementary design information to assist the user in matching security grades with the attack resistance times and staff response times required for each barrier in the facility.

CONCRETE MASONRY SECURITY GRADES

Using the test method described above, 8-in. (203-mm) concrete masonry walls, with and without window openings, have been shown to meet the highest security rating, Grade 1, with a representative barrier duration time of at least 60 minutes.

Typical Federal Bureau of Prisons masonry wall systems include: Type A, 8-in. (203-mm) normal weight concrete masonry with No. 4 (M #13) reinforcement at 8 in. (203 mm) on center both vertically and horizontally; and Type B, 8-in. (203-mm) normal weight concrete masonry with No. 4 (M #13) reinforcement at 8 in. (203 mm) on center vertically. Note that although both of these wall designs call for normal weight concrete masonry units, test results on a wall constructed using lightweight units (ref. 1) exceed the minimum requirements for a Grade 1 barrier, as do those for normal weight units.

Test Results

Five concrete masonry wall assemblies were tested (refs. 1, 2), and are described in Table 2. All five concrete masonry walls were able to withstand 600 blows and therefore achieve the Grade 1 rating in accordance with the draft ASTM standard for security walls. Additionally, the back side of each wall assembly was monitored after each sequence of 50 blows and no penetration or damage, including minor cracks, was observed during the 600 blows.

Subsequent to this testing, two of the wall assemblies were taken to failure. That is, walls #1 and #4 were subject to the blunt and sharp impactors in cycles of 50 blows apiece until the forcible breach defined in the draft security wall standard was observed. Wall #1 failed at 1,134 blows. Extrapolating the criteria in the draft ASTM standard, this corresponds to a rating of 1.8 hours. Wall #4 failed at 924 blows, which corresponds to a security rating of approximately 1.5 hours.

Test Specimens

All walls were constructed using 8 in. (203 mm) thick concrete masonry units with grout and one No. 4 (M #13) vertical reinforcing bar in each cell. Typical security wall construction provides stiffness at both the top and bottom of the wall through interconnection with the foundations below and the floor slab above. Rather than constructing individual flat wall panels with both a foundation below and a slab above as well as end returns (simulating stiffness provided by wall intersections), two four-sided closed cells were constructed: one for the wall panels without openings and one for the wall panels with simulated window openings. The walls were grouted into a reinforced concrete foundation and a reinforced concrete cap was used to fix the tops of the concrete masonry walls. Figure 1 shows the test panel configuration for the walls without window openings.

Table 2—8-in. (203 mm) Concrete Masonry Wall Test Specimens[a]

Wall #	Description	Average compressive strength, psi (MPa): Units	Masonry	Grout	Number of impacts:	Security grade:	Representative barrier duration time, min.:
1	NW (130.3 pcf, 2,090 kg/m^3), low strength CMU, low strength grout	2,850 (19.65)	2,440 (16.82)	4,040 (27.85)	1,134[b]	1	113[d]
2	NW (131.6 pcf, 2,110 kg/m^3) high strength CMU, low strength grout	4,820 (33.23)	3,540 (24.40)	3,440 (23.71)	600[c]	1	60
3	NW (131.6 pcf, 2,110 kg/m^3) high strength CMU, high strength grout	4,820 (33.23)	4,390 (30.27)	5,220 (35.99)	600[c]	1	60
4	LW (90.5 pcf, 1,450 kg/m^3) CMU, low strength grout	2,610 (17.99)	2,610 (17.99)	2,880 (19.85)	924[b]	1	92[d]
5	MW (107.3 pcf, 1,720 kg/m^3) CMU wall with window opening[e]	N/A	N/A	N/A	935[f]	1	93[d]

[a] CMU = concrete masonry unit; NW = normal weight, MW = medium weight, LW = lightweight per ASTM C 90 (ref. 3); mortar used conformed to ASTM C 270 Type S (ref. 4)
[b] wall was taken to failure
[c] wall was not taken to failure, testing was terminated at 600 blows
[d] extrapolated from Table 1
[e] phase 2 testing, wall panel with window opening (ref. 2)
[f] window frame was not taken to failure, testing was terminated at 935 blows

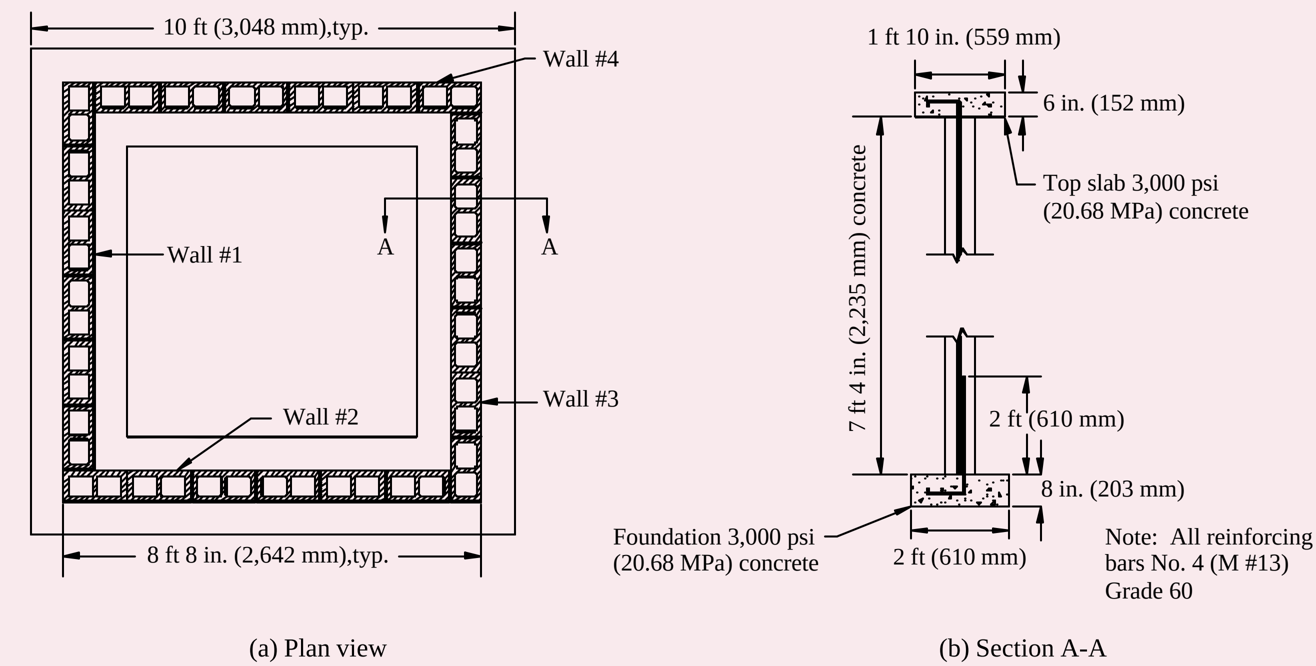

Figure 1—Prison Impact Test Wall Configuration

The four wall assemblies without openings differed in the types of concrete masonry units used and/or the grout strength used. These differences are fully described in Table 2. Three of the walls used normal weight concrete masonry units (with a concrete density of approximately 130 pcf (2,082 kg/m³)), and the fourth used lightweight units (with a concrete density of 90.5 pcf (1,450 kg/m³)).

For testing the walls without openings, the impacts were applied to the intersection of a bed and head joint at the midpoint of the wall. This location was chosen to be the predicted weak point of the wall assembly. Therefore, using the testing ram, a series of strikes were set against the target area and each strike was within ± 2 in. (51 mm) horizontally and vertically from the designated target area.

For the panel with the typical prison window frame (ref. 2), the window frame was manufactured to meet *Guide Specifications for Detention Security Hollow Metal Doors and Frames*, ANSI/HMMA– 863 (ref. 6) as required by the draft ASTM security wall standard. The nominal dimensions of the frame were 14 in. wide, 38 in. high, with a jamb width of 8 ¾ in (356 x 965 x 222 mm). The window frame was constructed of ¼ in. (6.4 mm) thick steel. The frame came equipped with masonry anchors that accommodated the vertical reinforcing bars in the masonry and then attached to the window frame. Once installed, the hollow area at the jamb was grouted solid. The intent of this impact testing is to check the integrity of the frame-to-masonry connection by striking at a corner of the window frame.

SPECIALIZED CONCRETE MASONRY UNITS FOR PRISON WALL CONSTRUCTION

Concrete masonry units are manufactured in many different shapes and sizes. Although conventional concrete ma-

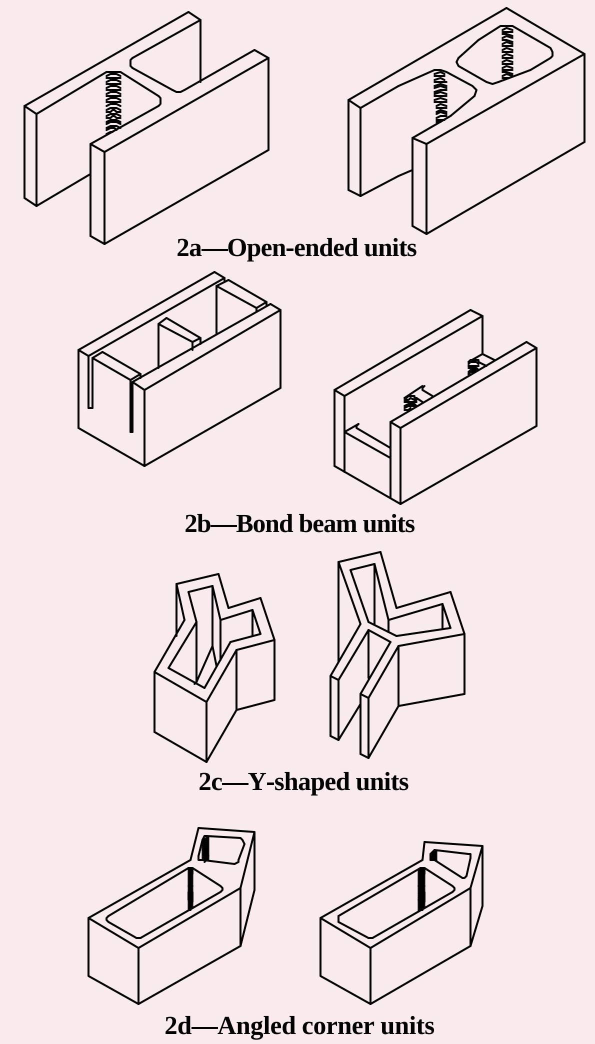

Figure 2—Concrete Masonry Units for Prison Construction

sonry units are often used for prison construction, some specialized units may also be available which are particularly well-suited for prison construction, such as those shown in Figure 2. Shapes intended to easily accommodate vertical and/ or horizontal reinforcement include open-ended units and bond beam units. Open-ended units, such as the A- and H-shaped units shown in Figure 2a, allow the units to be threaded around vertical reinforcing bars. This eliminates the need to lift units over the top of the reinforcing bar, or to thread the reinforcement through the masonry cores after the wall is constructed. Horizontal reinforcement and bond beams in concrete masonry walls can be accommodated either by saw-cutting out of a standard unit or by using bond beam units (Figure 2b). Bond beam units are either manufactured with reduced webs or with "knock-out" webs, which are removed prior to placement in the wall. Horizontal bond beam reinforcement is easily accommodated in these units.

Figures 2c and 2d show special Y-shaped and corner units developed specifically for prison construction. The Y-shaped units (with one 90° angle and two 135° angles) were developed to allow one corner of a rectangular prison cell to be used as a triangular chase for plumbing, electrical and HVAC service. By truncating the cell corner in this way, all repairs and maintenance can be accomplished without tradesmen ever having to enter the cell, thus reducing additional security risks. The Y-shaped and corner units allow this construction, as well as construction of nonrectangular cells, without creating continuous vertical joints in the wall.

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