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NATIONAL BUREAU OF STANDARDS REPORT

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Requirements for Concrete-Masonry Construction (Revision of NBS Report 2462)

By

Cyrus C. Fishburn

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
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To

Office of Chief of Engineers
Department of the Army

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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1. SCOPE

This report suggests criteria to be followed for the use of concrete masonry in military construction. It discusses the selection of materials, the preparation of drawings and specifications for the structure, the control of shrinkage cracking in the walls, the erection of the walls and their painting. The report is not concerned with floors, roofs or other constructions not involving the use of concrete masonry units except insofar as such constructions affect the use of concrete masonry, particularly of concrete masonry walls.

2. CODES, STANDARDS AND SPECIFICATIONS

The American Standard Building Code Requirements for Masonry (ASA A41.1-1953), hereinafter referred to as A41.1, is the basis for masonry design and construction. Sections of this code that are applicable to concrete masonry are automatically included in this report without further reference and should be followed, unless modified herein. It should be clearly noted that any requirement in this report that conflicts with any codes, standards or specification takes precedence over the applicable section or sections of such codes and standards.

3. CONCRETE MASONRY UNITS

A concrete masonry unit is a building unit made from portland cement and aggregate with or without the addition of other suitable materials. The units should conform with the requirements of the current ASTM Standards. These standards are:

Hollow Load-Bearing Concrete Masonry Units,
ASTM C90-52,

Hollow Nonload-Bearing Concrete Masonry Units,
ASTM C129-52,

Solid Load-Bearing Concrete Masonry Units,
ASTM C145-52

Aggregate used in concrete masonry units should comply with the requirements of one of the following ASTM Standards:

Concrete Aggregate - ASTM Standard C33-53T

Concrete Aggregate, Lightweight - ASTM
Standard C130-42

A new proposed ASTM specification for "Lightweight Aggregate for Concrete Masonry Units" may soon be approved as a tentative Standard, possibly under an ASTM number other than C130. When this specification becomes available, any requirements for staining and surface popouts contained in it should be noted and unless the aggregates are known to be sound, tests for staining and surface popouts should be made. These tests are listed in section 9 of this report. However, the test for surface popouts should be made on the units or pieces of the face shells of the units, not the aggregates. When there is evidence that cinder or other aggregate block produced in an area may tend to stain or pop, the use of such block as a facing may be restricted.

3a. Units for fire walls

Hollow concrete masonry units intended for use in fire resistant walls should meet the requirements of Underwriters' Laboratories Standard for Concrete Masonry Units, Subject 618. If Underwriters' certificate is required, it should be so stated in the specifications.

3b. Concrete building brick

The use of concrete building brick should be incidental only and the use of larger concrete masonry units is preferred. Concrete building brick, if used, should comply with the requirements of ASTM Standard C55-52.

3c. Shrinkage

The potential shrinkage of concrete masonry units is affected by the kinds of materials used and by manufacturing and curing conditions at the plant. The potential shrinkage is an important factor affecting both the extent and the control of shrinkage cracking in concrete masonry structures. Concrete masonry units should, therefore, be classified into two groups, group 1 or group 2, as listed below:

Drying Shrinkage Classification of Concrete Masonry Units[a]

Kind of masonry unit	Weight of masonry unit per cu ft of concrete lb	Linear shrinkage[b] Group 1 percent	Linear shrinkage[b] Group 2 percent
Concrete brick	100 or more	no limit	0.03 or less
Hollow or solid concrete block	105 or more	no limit	0.04 or less
Hollow or solid concrete block	less than 105	no limit	0.05 or less

a/ The control of shrinkage cracking, using group 1 and group 2 units is discussed in Section 5.
b/ See par. 9b for method of testing.

3d. Moisture content

The average moisture content of all concrete masonry units at the time of delivery should not exceed 30 percent of the total absorption of the units. On approval by the Division Engineer, the limit of 30 percent on moisture content may be increased in regions of high humidity (Mean Relative Humidity of 80 percent or more) to 35 percent and may be reduced to 25 percent in regions of low humidity.

3e. Storage

Before erection and while in storage at the site of the job, units must be protected from moisture and kept dry prior to laying. No units should be placed directly upon the ground while being stored. The contractor should be held responsible for protecting the units. Units which fail to meet the moisture-content limitation at any time during the storage on the job, should be dried and should not be laid until tests prove them to be satisfactory.

3f. Manufacture

Units should be of the same manufacture and composition for each building, unless otherwise approved by the Contracting Officer. When it is permitted that the units be made by more than one manufacturer for use in the same building, they should be of similar composition, size, and appearance. All units should be sound and free from cracks or other defects which would interfere with their proper setting or impair the strength, appearance, or durability of the construction.

3g. Special shapes

Concrete masonry units of special shapes such as beam lintel blocks and bond beam blocks, see figure 1, should conform with the general requirements for concrete masonry stretcher units, excepting shape and overall dimension.

3h. Dimensions of units

Concrete masonry units should be of modular dimensions where available and should be used in modular designs. (See section 1.6.11.2 of A41.1).

4. MORTAR, GROUT AND THEIR USE

To obtain masonry joints of high quality with ordinary construction methods, an intimate and complete contact of the mortar with the surface of the masonry unit is necessary. Although the skill and the amount of effort exerted by the mason affect the quality of the joints in masonry, the quality and the condition of the materials are the important factors. Mortars which have low water retentivities tend to stiffen so rapidly when in contact with the surface of a dry, absorptive masonry unit that they become too dry and stiff to permit an intimate and complete contact of the mortar when the second unit is pressed against it. Also, mortars of low water retentivity tend to "bleed" if allowed to stand. The wetness (flowability) of the mortar being used by the mason has an important influence on the extent and intimacy of the bond between the mortar and the units; the wetter the mortar the more complete and the stronger the bond between mortar and unit and the more watertight the joint.

4a. Definition

Mortar is a plastic mixture of cementitious materials, fine aggregates and water used to bond masonry or other structural units. Mortar of pouring consistency is termed grout.

4b. Mortar specifications

Mortar, mortar materials and proportioning should comply with the requirements of ASTM Standard C270-52T. This Standard contains two alternate specifications designated as the Property Specifications and the Proportion Specifications. Either of these two alternate specifications for mortar of types A-1, A-2 and B may be used, provided that mortar specified under the Proportion Specification meets the requirement for water retention given in Section 4c. Mortar of types C and D should not be specified. The compressive strength requirements (Property Specification) for these mortars are:

Mortar Type	Average Compressive Strength of 2-in. Cubes at 28 Days psi
A-1	2500
A-2	1800
B	750

4c. Water retention

Mortar made of the same materials and proportions to be used on the construction, mixed to an initial flow of 125 to 140 percent, should have a flow after suction (water retention) of 75 percent or more of that immediately after mixing. The apparatus to be used and the method of determining water retention should be in accordance with Section 30 of ASTM Standard C91-51, except that the mortar should be of the materials, proportions and initial flow described above at the head of this section (4c). Mortars specified under the Proportion Specification of C270-52T should be tested and required to meet the minimum water retention of 75 percent. The water retention of each type of mortar used should be measured at least once each week during construction of the masonry.

4d. Choice of mortar

Masonry should be laid in mortar of the types specified in the following table:

Kind of masonry	Type of mortar
Foundation	
Walls of solid units	A_1, A_2 or B
Walls of hollow units	A_1 or A_2
Hollow walls and cavity walls	A_1 or A_2
Masonry other than foundation masonry	
Piers of solid masonry	A_1, A_2 or B
Piers of hollow units	A_1 or A_2
Walls of solid masonry	A_1, A_2 or B
Walls of hollow units; load bearing or exterior walls and hollow walls 12 in. or more in thickness	A_1, A_2 or B

Masonry other than foundation masonry (Cont'd)

Hollow walls less than 12 in. in thickness where assumed design wind pressure:1/	
(a) exceeds 20 lb/ft^2	A_1 or A_2
(b) does not exceed 20 lb/ft^2	A_1, A_2 or B
Linings of existing masonry	A_1 or A_2
Masonry other than above	A_1, A_2 or B

1/ For design wind pressures, consult Am. Std. Building Code Requirements for Minimum Design Loads in Buildings and other Structures, ASA A58.1 (current edition).

4e. Thickness of mortar joints

Wherever possible, the thickness of both horizontal (bed) and of vertical (head and collar) joints should be 3/8 in. (modular dimension).

4f. Joints in hollow-unit masonry

Full mortar bedding of both the face shells and webs of hollow concrete masonry units should be required as follows:

(a) Under the first or starting course laid on footings and solid foundation walls
(b) In piers, columns and pilasters intended to carry heavy loads

All other hollow units need be bedded under the face shells only. The first course of single-wythe panel walls containing weep holes and supported on spandrel beams should be bedded under the face shells only to permit drainage of water to the weep holes, see figure 11. The use of weep holes in such walls is in accordance with OCE policy. Mortar for vertical (head) joints should be applied over the full width of the face shells.

4g. Joints in solid-unit masonry

For masonry of solid units, the bed and head joints should be filled as solidly as is practicable. Mortar in the bed joints should be spread over the full area of the block and may be furrowed. Similarly, mortar for the head joints should be heavily buttered and applied over the full area of the ends of the block.

4h. Type of exposed joints

If the weather side of a wall is to be coated with a portland cement paint or a pneumatically applied cementitious coating, the joints in the exposed (weather) face should be cut flush with the faces of the units. The rough texture of the cut joint provides a better bonding surface for a cementitious coating than does the smooth compacted mortar surface of the tooled joint. The durability and the weather resistance of the coating covering the joints may, therefore, be improved by cutting, not tooling the joints.

4i. Time limit in use of fresh mortar

Mortars which have greatly stiffened because of chemical reaction (hydration) should not be used but the stiffening resulting from the evaporation of moisture from the mortar should not be confused with the effects of chemical reaction. Determination of the cause of stiffening is difficult and an arbitrary rule on a time limit for the use of mortar may be substituted for this determination. At air temperatures of 80°F or higher, mortars should be used and placed in the wall within two and one-half hours after mixing. At temperatures of less than 80°F the mortar should be used within three and one-half hours after mixing. Mortar which is not used during the time intervals given above should be discarded and thrown away. If the cement or cements used in the mortar have been tested and the observed time of initial set, as determined under ASTM Standard C266-51T (Gilmore Method) is known, an alternative method of determining the time interval, during which the mortar should be placed in the wall, may be used. These alternative time intervals are:

Air temperature	Time interval after mixing
80° F or higher	Time of initial set less 1 hr.
Less than 80° F	Time of initial set less 1/2 hr.

If the mortar contains two cements (a portland and a masonry cement), the least observed time of initial set should be used. Under laboratory conditions, most portland and masonry cements will attain an initial set in three to five hours. However, at high temperatures and under other possible job conditions the hydration of the cement may proceed faster than in the laboratory.

4j. Retempering of mortar

Mortars which have stiffened should be retempered to restore their workability and water should be added as frequently as needed during the maximum time intervals given in section 4i above. Masons should be encouraged to use as much mixing water as is practicable without impairing the workability of the mortar. Although the strength of the mortar may be slightly reduced by the liberal use of water in mixing and retempering, the lack of retempering may seriously reduce the flexural and the tensile strength of the masonry because of poor bonding of the units to dry, stiff mortar.

4k. Grout

Grout should be Type A-1 or Type A-2 mortar to which is added water to produce consistency for pouring without segregation of constituents of the mortar. Type A-1 grout should be used with Type A-1 mortar; either Type A-1 or Type A-2 grout should be used with Type A-2 mortar.

5. CONTROL OF SHRINKAGE CRACKING

The shrinkage cracking of concrete masonry may be controlled by drying the units, by selecting units having a limited potential shrinkage (Group 2 units), and by the use of joint reinforcement, bond beams, and control joints. The drying and the selection of units are discussed in Section 3 of this report. The following requirements for bond beams, control joints and joint reinforcements are based chiefly on the use of Group 1 units for which there are no limits on maximum linear shrinkage. Summaries of the requirements for control joints, bond beams and joint reinforcement for masonry of both Group 1 and Group 2 units are tabulated at the end of this Section. The measures used to control shrinkage cracking in concrete masonry walls should not be confused with the use of expansion-joints and contraction-joints in buildings. A short discussion of expansion-joints in buildings is contained in the next paragraph of this section.

5a. Expansion joints

Expansion joints should completely separate the building structure from bottom to top along a vertical plane and should be capable of functioning either as an expansion joint or as a contraction joint, as the structure expands or contracts. There is no uniform practice for designing the joints. In a framed structure, the division of the building may be accomplished by using double columns and double girders or cantilever floor and roof slabs which meet at the joint. The joint may be protected from leakage and the weather by sliding plates or a metal sheet. When required, expansion joints may be placed at changes in elevation of the foundations or superstructures and at junctions in L-,T- or U-shaped buildings. Reinforced concrete buildings of 300 ft. or more in length have been built without expansion joints and, when properly reinforced, have not cracked badly. However, complete separation of the structure should be made with expansion joints at intervals not exceeding 200 ft. in long straight buildings. The discussion of shrinkage control joints in concrete masonry walls, given later in this section, does not pertain to expansion joints. While a shrinkage control joint may be modified and used as part of an expansion joint through a structure, it should then be defined as an expansion-contraction joint and not as a control joint.

5b. Bond beams

Bond beams may consist of bond beam or lintel beam units filled with reinforced concrete, see figure 2 for bond beam and lintel beam sections. Recessed lintel units and jamb units are also made and are available in some sections of the country. Concrete should conform with the requirements of OCE Guide Specification CE204, Class B 2500/in.[2]. Reinforcement should consist of at least two No. 4 deformed bars or the equivalent in cross sectional area. The reinforcement should conform with the requirements of ASTM Standard A305-50T. When the concrete fill in the beam is deeper than 7 in. at least half as much reinforcement should be added near the top of the beam as is required in the bottom. Cast-in place reinforced concrete beams may be used instead of filled masonry-unit bond beams. Cast-in place or precast concrete beams may be used as lintels.

5c. Function of bond beams

The functions of bond beams are as follows:

(a) To reduce the effects on the masonry of differential volume changes between the foundation and superstructure walls.

(b) As a continuous interlocking structural tie connecting the exterior load bearing walls of buildings whose dimensions are small enough not to require expansion or expansion-contraction joints. They may be similarly used between the expansion joints in larger buildings.

(c) As a structural member transmitting lateral loads on the wall to other connecting structural elements.

(d) To minimize shrinkage cracking at wall openings, particularly when used as a more or less continuous lintel. The bond beam may also control the shrinkage cracking in the masonry immediately above and below it but its effectiveness diminishes rapidly with vertical distance from the beam. The efficiency of steel to control shrinkage cracking is greater when used as joint reinforcement than when used in a bond beam.

It is evident that the bond beam functions not only as a structural element but also as a control against shrinkage cracking. The use of the bond beam as a structural element alone, is further discussed in section 6. In general, bond beams may be cut at control joints provided their structural functions as lintels and as members transmitting lateral loads to other structural elements are not thereby impaired. If a bond beam is cut at a control joint, provision should be made to transmit lateral forces and to give protection from the weather at the cut section. If joint reinforcement is used in lieu of control joints to control shrinkage, the bond beam need be cut only if its length is excessive, as where expansion joints are used.

5d. <u>Location of bond beams</u>

Bond beams should be placed in the top courses of concrete masonry foundation walls more than 30 in. in height. If the bond beam is not used, the footing should be reinforced. Bond beams should also be placed at or near the top course of all load-bearing walls built of concrete masonry units. Where high wind loads may be expected and where large volume changes may occur in the masonry, additional bond beams may be placed between the top and bottom of concrete masonry walls. For walls of Group 1 units, bond beams should be placed at vertical intervals of not more than 12 ft, but not between openings. Bond beams should also be placed in non-bearing walls used as lateral support for load-bearing walls and at the same elevations as in the load-bearing wall but not between openings, see section 6c. When the bond beam is not broken, at a control joint, a dummy joint simulating a control joint may be placed in the exposed face of the bond beam to give the appearance of a continuation of the joint through the beam. Bond beams should be terminated at expansion joints. The minimum requirements for the use and location of bond beams are tabulated at the end of Section 5 and are summarized below:

1. At the top of concrete masonry foundation walls more than 30 in. high (provided the footing is reinforced).

2. At or near the top of load-bearing concrete masonry walls. The bond beam should be placed in the top course if the top of the wall is tied to the roof or if the wall is subjected to lateral thrust from the roof.

3. In walls of Group 1 units at intervals not exceeding 12 ft. in wall height but not between openings.

5e. Control joints

Shrinkage control joints are vertical joints which provide a continuous vertical separation between bond beams through the entire thickness of a concrete masonry wall, including any facing or rigid finishes. The joints may be masked and the possibility of leakage of rain through them may be reduced by the use of pilaster blocks and by recesses in monolithic concrete column faces. Provision should be made for the transfer of lateral loads across the joint. This may be done by using control joint blocks or by filling the space between open-end units with mortar or concrete, see figures 3, 4, and 5. The joints on the weather side of the wall should be faced and sealed with plastic calking compound. Formed synthetic rubber or vinyl plastic stripping may be a suitable substitute for calking compound. The vertical joint behind the calking should contain mortar and the mortar should be applied to both faces of the wall. The mortar on the inside face of the joint may be raked, for appearance.

5f. Function and location of control joints

The function of a control joint is to assist in relieving the horizontal stresses in straight wall sections, resulting from moisture and temperature movement. Shrinkage control joints are primarily intended to function as contraction joints. If considerable volume changes occur in concrete masonry walls, the control joint may also be required to function as would an expansion-contraction joint. In such cases it may be undesirable to place mortar in the vertical joint but to fill with calking only. Control joints should be placed at intersections where the intersecting walls are longer than 12 feet. The joint may be placed in the cross wall at a distance equal to 1/2 the height of the cross wall from the intersection. If the intersecting walls are not needed as lateral supports for each other or if they are interconnected with bond beams, the control joint may be placed at the wall intersection, preferably on the inside face of exterior walls. It is not implied that control joints should be used at the corners of the exterior walls in buildings of square or of rectangular shape, especially if the walls contain joint reinforcement. Control joints should not pass through bond beams, sills or lintels if cutting of the bond beam or lintel impairs the structural stability of the wall or of the building as a whole. When placed at or below wall openings, the control joint may require the use of slip joints under the ends of lintels and will prevent the effective use of joint reinforcement to control the width of shrinkage cracks at these highly stressed locations. The use of slip joints is not desirable. Control joints and methods of bonding intersecting walls are shown in figures 6 and 7.

5g. Spacing of control joints in straight wall sections

The proper spacing between control joints in straight walls depends upon the restraints to which the wall is subjected, the exposure conditions, the amount and distribution of reinforcement,if used, and the kind of block or amount of shrinkage. This spacing should be equal to or slightly less than the more or less uniform distance between vertical shrinkage cracks that would normally occur if the wall were built without control joints. For walls of Group 1 units, without joint reinforcement, this spacing should not exceed 15 ft, see option 2 of the table at the end of this section. For walls of Group 2 units, the spacing should not exceed 30 ft. If the control joints are not properly placed and if the walls are without joint reinforcement, vertical shrinkage cracks may occur. These cracks may function instead of the control joints and may be unsightly, especially where they pass through the units. For straight walls, it is possible that joint reinforcement which strengthens the masonry and which requires no maintenance is more reliable in controlling shrinkage than is the control joint. Since control joint blocks are not available in 4-in. block widths and since the 4-in. thick blocks are flat ended making it difficult to provide lateral stability at a control joint, the joint reinforcement may be preferred to control joints in cavity walls using 4-in. blocks. The minimum requirements for the use and location of control joints are tabulated at the end of Section 5 and are summarized below:

1. At the wall intersections in L-, T-, and U-shaped buildings where expansion joints are not used.

2. At or near cross wall intersections if the intersecting walls are both 12 ft. or more in length.

3. If joint reinforcement is not used, control joints should be placed at intervals not exceeding 15 ft. in walls of Group 1 units and 30 ft. in walls of Group 2 units.

5h. Joint reinforcement

Joint reinforcement consists of flat (not rolled) strips of welded wire fabric in the bed joints of the masonry. The distance between the centers of the two longitudinal wires in a strip depends upon the width of the block and for blocks having face shells 1 1/4 in. thick should be 2 in. less than the nominal block width. The longitudinal wires may be either smooth or preferably deformed and zinc-coated and should not be smaller than size No. 8, American Steel and Wire gauge. Since the stress in smooth longitudinal reinforcement is developed principally by bearing of the cross wires in the mortar bed, the cross wires should intersect above or below the longitudinal wire and should be spaced not more than 6 in. apart center to center. To reduce the possibility of exposing the reinforcement in the wall faces the cross wires should extend only to the outer sides of the longitudinal wires and should preferably be zinc-coated. If the longitudinal wires are deformed, the cross wires should be spaced not more than 16 in. on centers and may be placed between the longitudinal wires and in the same plane. The cross wires should not be smaller in size than No. 12 A.S.& W. gauge. Joint reinforcement should be furnished in straight flat pieces of convenient lengths ranging from 10 to 20 or more feet in length. Special shapes of joint reinforcement may be provided for wall intersections and corners, thereby reducing the amount of cutting and bending needed on the job. Joint reinforcement should terminate at control joints. The wire used in joint reinforcement should meet the requirements of ASTM Standard ASTM Standard A82-34.

5i. Function of joint reinforcement

Under the usual field service conditions and regardless of the kinds of units used, it is probable that the extensibility of plain, unreinforced walls built without control joints will be exceeded and some shrinkage cracking will occur if the free linear shrinkage of the units is equal to or greater than 0.02 percent. After the first cracks occur, their width, but not necessarily their number, would tend to increase with further increase in shrinkage. Joint reinforcement will not prevent the appearance of fine shrinkage cracks in the masonry. It will tend to increase the number of the cracks and to decrease their width, and since most of the cracks in reinforced walls will occur at head joints, it will greatly reduce the number of cracked blocks. If the percentage of reinforced bed joints is 50 or greater and if the shrinkage of the units is not too great, it is possible that the widths of shrinkage cracks may be held to a maximum of about 0.01 in.[2] with a minimum use of control joints. It should be noted that the width of cracks will also be dependent upon the percentage of reinforced joints as well as on the amount of steel placed in a joint. Joint reinforcement should preferably be used at wall openings and at other points where high tensile stresses resulting from shrinkage are probable. In general, joint reinforcement strengthens the masonry, requires no maintenance, and may be preferred to control joints to control shrinkage cracking in concrete masonry walls, especially in cavity type walls. Since a given amount of steel may be more widely distributed as joint reinforcement than when concentrated in a bond beam, the joint reinforcement should be preferred to bond beams to control shrinkage cracking.

5j. Use and location of joint reinforcement

At openings in walls of Group 1 units, joint reinforcement should be placed in the first bed joint over simply supported lintels and in the first two bed joints under a sill. At openings in walls of Group 2 units, joint reinforcement should be placed only in the first bed joint under a sill. The joint reinforcement at openings should extend at least 20 in. beyond the ends of sills and lintels or through the full distance to the end of the wall whichever is the smaller. Joint reinforcement at openings in a concrete frame building and at other openings is shown in figures 8, 17 and 18. Except that the previously stated minimum requirements for control joints be followed, joint reinforcement, in addition to that required at openings, may be used in lieu of or in conjunction with control joints. When used in lieu of control joints, the joint reinforcement should be placed in every bed joint in walls of Group 1 units and in alternate bed joints in walls of Group 2 units. Except for that required at openings, no joint reinforcement is required in walls 12 ft, or less, in length. No joint reinforcement is required in the bed joint supporting a bond beam. The minimum requirements for the use and location of joint reinforcement are listed at the end of Section 5.

5k. Splices in joint reinforcement

Joint reinforcement should be lapped at splices and the splice should develop the tensile strength of the longitudinal steel. For smooth longitudinal steel, the lapped splices should contain at least one cross wire located near the end of each strip. The lapped splices in deformed joint reinforcement may also, and preferably should, contain cross wires. If the cross wires are placed in the same plane as

2/ Approximate value only, not based on field experience.

that of the deformed longitudinal wires, heavier joint reinforcement may be used for a given joint thickness than is the case when the cross wires extend over the longitudinal wires. For a 3/8-in. thick bed joint, No. 8 is the maximum size smooth wire that may be used without thickening the joint; if deformed wire is used with cross wires in the same plane, the longitudinal wires may be No. 6 size, see sections A-A and B-B of figure 9.

Summary of Minimum Requirements for Bond Beams, Control Joints and Joint Reinforcement in Concrete Masonry Walls [a]

	Bond Beams	Control Joints	Joint Reinforcement
Option 1[b]	At top of concrete masonry foundation walls over 30 in. high. At or near top of load-bearing walls (at top course if wall is subjected to thrust from the roof). In load-bearing walls of Group 1 units, at vertical intervals not exceeding 12 ft. but not between openings. In non-bearing walls used as lateral supports for load-bearing walls and at same elevations as in the load-bearing walls but not between openings.	At wall intersections L-, T- and U-shaped buildings where expansion joints are not used.[d] At or near cross walls if the intersecting wall is 12 ft. or more in length. (No control joint should pass through a bond beam lintel, sill or special joint reinforcement at openings if the structural function of the bond beam or lintel would thereby be impaired.	<u>Walls of Group 1 Units:</u> In every bed joint of wall sections exceeding 12 ft. in length. At openings, in first two bed joints beneath a sill and in the first bed joint over a lintel in walls less than 12 ft. in length. <u>Walls of Group 2 Units:</u> In alternate bed joints of wall sections exceeding 12 ft. in length. At openings, in the first bed joint under a sill.
Option 2[c]	Same as Option 1.	<u>Walls of Group 1 Units:</u> At intervals of not more than 15 ft. and as in Option 1.	<u>Walls of Group 1 Units:</u> At openings, in first two bed joints under a sill and in the first bed joint over a lintel.

	Bond Beams	Control Joints	Joint Reinforcement
		Walls of Group 2 Units: At intervals of not more than 30 ft. and as in Option 1.	Walls of Group 2 Units: At openings in the first bed joint under a sill.

a/ Combinations of the minimum requirements listed in Options 1 and 2 may be satisfactory.
b/ Option 1 gives minimum requirements using joint reinforcement.
c/ Option 2 gives minimum requirements using control joints.
d/ The control joint is primarily a contraction joint. However, there may be locations, as in L-, T-, or U-shaped building which do not contain expansion joints completely dividing the structure, where the control joint should provide for both expansion and contraction as the masonry in the wall expands or contracts.

6. STRUCTURAL DESIGN

As previously stated, in section 2, the American Standard Building Code Requirements for Masonry A41.1 are the basis for structural design. Insofar as these requirements are applicable to concrete masonry, they should be followed without further reference unless modified herein. The necessity for modification results chiefly from the use of control joints and bond beams (section 5) and their effects on the structural stability of the walls and of the structure as a whole. The modifications pertain chiefly to single wythe walls of either hollow or solid units and to cavity walls of hollow units.

6a. Compressive stresses

The compressive stresses on the gross cross-sectional area of concrete masonry should not exceed the values listed below:

Kinds of masonry and of concrete masonry units	Type of Mortar A_1	Type of Mortar A_2	Type of Mortar B
	lb/in.^{2}	lb/in.^{2}	lb/in.^{2}
Masonry of hollow load-bearing concrete masonry units	85	75	70
Solid masonry of concrete brick and of solid load-bearing concrete masonry units:			
Grade A	175	160	140
Grade B	125	115	100
Grouted solid masonry of concrete brick and of solid load-bearing concrete masonry units:			
Grade A	275	215	155
Grade B	225	175	125
Piers of hollow units, cellular spaces filled as in Section 6e	105	95	90
Hollow walls, cavity 1/ or masonry bonded			
Solid units, Grade A	140	130	110
Solid units, Grade B	100	90	80
Hollow units	70	60	55

1/ On gross cross-sectional area of wall minus area of cavity between wythes (leaves). The allowable compressive stresses for cavity walls are based upon the assumption that the floor loads bear upon but one of the two wythes. When hollow walls are loaded concentrically, the allowable stresses may be increased by 25 percent.

6b. Design against seismic forces

The stresses used in the design of concrete masonry structure against seismic forces should conform with the requirements of the Uniform Building Code of the Pacific Coast Building Officials Conference, insofar as they are applicable.

6c. Lateral support

Lateral support may be obtained by cross walls, piers, pilasters, columns, or buttresses, when the limiting distance is measured horizontally, or by floors and roofs when the limiting distance is measured vertically. Sufficient bond or anchorage should be provided between walls and their supports to resist the assumed horizontal forces acting either inward or outward. The structural members relied upon for lateral support should have sufficient strength and stability to transfer the horizontal forces, acting in either direction to adjacent structural members or to the ground. Care should be taken that the structural members such as cross walls, roofs and columns that are relied upon for lateral support do not as a result of changes in temperature and in moisture content, exert excessive or unusual thrust against or pull upon the walls they are intended to support. Cross walls more than 12 ft in length, used as lateral supports for the walls, should contain control joints. If the control joint is placed at the intersection, bond beams should be used as outlined in Section 5. The control joints should preferably be placed about one-half of the wall height from the wall intersection but not more than 12 ft from the intersection. The bond beams in the intersecting walls should be interlocking, as continuous as possible and at the same elevations in each wall. Details showing methods of bonding concrete masonry walls to each other and to columns, roofs, and floors are shown in figures 6, 7, 8, 10, 11, 12, 13, 14 and 15.

6d. Ratio of height or length of wall to wall thickness

The ratio of unsupported height to nominal thickness or the ratio of unsupported length to nominal thickness (one or the other but not necessarily both) for load-bearing walls should not exceed 20 if of solid concrete masonry units and should not exceed 18 if of hollow concrete masonry units. Similarly, this ratio should not exceed 18 for walls of hollow masonry including cavity walls. In computing the ratio for cavity walls, the value for thickness should be the sum of the nominal thicknesses of masonry in the inner and outer wythes. The air space is not included in the thickness used for computing this ratio. In walls composed of different kinds or classes of units, the ratio of height or length to thickness should not exceed that allowed for the weakest of the combination of units.

6e. Height of piers

The unsupported height of piers should not exceed 10 times their least dimension provided that when hollow concrete units are used for isolated piers to support beams or girders, their unsupported height shall not exceed 4 times their least dimension unless the cellular spaces are filled solidly with concrete or either Type A-1 or A-2 mortar.

6f. Thickness of single-wythe bearing walls

The minimum thickness of bearing walls built of a single wythe of either hollow or of solid concrete masonry units should be 8 in. for walls less than 12 ft in height. For walls over 12 ft in height, the minimum thickness should be 12 in. for the uppermost 35 ft in height and should be increased 4 in. for each successive 35 ft or fraction thereof measured downward from the top of the wall.

6g. Thickness of stiffened bearing walls of solid units

Where solid masonry bearing walls built of solid units are stiffened at distances not greater than 12 ft apart by masonry cross walls or by reinforced concrete floors, they may be of 12 in. thickness for the uppermost 70 ft measured downward for each successive 70 ft or fraction thereof.

6h. Thickness of cavity walls

Cavity walls, either bearing or nonbearing, may be built of solid or of hollow concrete masonry units and should not exceed 35 ft in height except that the height of 10 in. thick cavity walls should not exceed 25 ft above the supports of such walls. The facing and backing wythes of cavity walls. The facing and backing wythes of cavity walls should have a minimum thickness of 4 in. and the cavity should be not less than 2 in. or more than 3 in. in width.

6i. Thickness of nonbearing exterior walls

Nonbearing exterior single-wythe concrete masonry walls may be 4 in. less in thickness than required for bearing walls, except that the thickness should be not less than 8 in.

6j. Thickness of nonbearing partitions

Nonbearing concrete masonry partitions may be 4 in. less than required for bearing walls except that the thickness should be not less than 4 in. The distance between lateral supports of nonbearing partitions should not exceed 36 times the actual thickness of the partition including plaster.

6k. Decrease in thickness

Where cavity walls and walls of hollow units are decreased in thickness, a course or courses of solid masonry should be interposed between the wall below and the thinner wall above, or special units or construction should be used that will adequately transmit the loads from the shells above to those below.

6l. Thickness of foundation walls

Foundation walls should be of sufficient strength and thickness to resist lateral pressures from adjacent earth and to support their vertical loads without exceeding the allowable stresses. Foundation walls or their footings should extend below the level of frost action and should be not less in thickness than the walls immediately above them. Basement and cellar foundation walls should be parged on all surfaces in contact with the ground.

6m. Depth of foundation walls

Solid foundation walls of solid masonry units that do not extend more than 5 ft. below the adjacent finished ground level may be 8 in. in minimum thickness; cavity walls and walls of hollow units that do not extend more than 4 ft. below the adjacent finished ground level, may be 10 in. and 8 in., respectively, in minimum thickness. Those depths may be increased to a maximum of 7 ft. when soil conditions warrant such increase. The total height of the foundation wall and the wall supported should not exceed that permitted by these requirements for 8 in. walls.

6n. Multiple wythes in other than cavity walls

Walls may be of more than one unit in thickness and when so built the wythes and units should be bonded as in Section 7.1.1, Section 7.1.2, or Section 7.2 of A41.1.

6o. Bonding of cavity walls

The facing and backing of cavity walls should be bonded with 3/16-in. diameter steel rods or metal ties of equivalent stiffness embedded in the horizontal joints. There should be one metal tie for not more than each 4 1/2 sq. ft. of wall area. Ties in alternate courses should be staggered and the maximum vertical distance between ties should not exceed 18 in., and the maximum horizontal distance should not exceed 36 in. Rods bent to rectangular shape should be used with hollow masonry units laid with the cells vertical, see figure 16; in other walls the ends of ties may be bent to 90 degree angles to provide hooks not less than 2 in. long. Additional bonding ties should be provided at all openings, spaced not more than 3 ft. apart around the perimeter and within 12 in. of the opening. Ties should be of corrosion-resistant metal, or should be coated with a corrosion-resistant metal, or other approved protective coating.

6p. Bonding of intersecting walls

At corners and intersections where one wall is needed as lateral support for the others, the walls should be bonded by one or more of the methods given below.

(a) Laying at least 50 percent of the units in a true masonry bond at the intersection or corner.

(b) By the use of joint reinforcement or metal ties at the intersection or corner.

(c) By the use of bond beams.

If an intersecting wall is 12 ft. or more in length, a control joint is required at or near the intersection (see Section 5). The control joint should preferably be placed a distance equal to about one-half the story height from the intersection rather than at the intersection. If the control joint is placed at the intersection, the walls should be connected with interlocking bond beams if lateral support is required. Regardless of the location and use of control joints, interlocking bond beams may be used to insure lateral support for a wall.

6q. Bonding of enclosure walls to columns

Methods of bonding nonbearing concrete masonry enclosure walls to steel columns and to concrete frame construction (for lateral support) are illustrated in figures 10, 11, and 12. Walls between concrete columns should preferably be anchored to the sides of the columns as in figure 10. In spandrel beam constructions the tops of the walls may be keyed to the bottoms of the spandrel with mortar. Since the top of the walls may shrink from the bottom of the spandrel, it may be better to anchor the walls to the columns and provide a reglet to prevent rain penetration as shown in figure 11. When the roof framing is supported on steel columns and the columns are needed to provide lateral support for the walls, the method of anchoring the walls to the columns may be as shown in figure 12. Bond beams may be used at the anchor courses (figure 12) to increase the lateral stiffness of the walls.

6r. Reinforced masonry

Where desirable, concrete masonry may be designed and built to sustain bending and compressive load producing tensile stresses and compressive stresses higher than those permitted in Section 6a. This may be done by the proper use of steel reinforcement and grout in the masonry. Such reinforcement, if used, should be in addition to the use of joint reinforcement to control shrinkage cracking, discussed in Section 5. Codes and specifications for the design and construction of reinforced masonry, other than those pertaining to seismic design, are not widely available in printed form. However, an American Standard Building Code Requirement for Reinforced Masonry, A41.2, is under consideration and may become available at some future date.

6s. Wall openings

In general, openings in exterior load bearing concrete masonry walls should be located so one continuous bond beam may serve as a lintel for all openings. This may require transoms for doors and a resection of window sizes. Wherever possible window heads should be located under a spandrel beam or under the top level bond beam in a story height. The jambs, sills, and lintels at openings in concrete masonry walls may be of reinforced concrete. Ordinarily, the precast concrete, poured concrete, or the filled masonry unit lintel is the only reinforced structural element required at wall openings. Lintels should be designed for shear and moment and should be of sufficient stiffness to carry the superimposed load without deflection of more than 1/360 of the clear span. Information on the design of lintels in concrete masonry has been prepared and published by the National Concrete Masonry Association. The minimum length of bearing for simply supported lintels should be as shown in figure 2. The use of control joints at wall openings should not entail or require that slip joints or unbonded bearing surfaces be used under one or both ends of a lintel. Steel door and window frames at openings should not be in direct contact with the masonry or the lintel at the top of the opening unless the frame is capable of supporting the loads that may be placed upon it as a result of shrinkage of the masonry, without excessive deflection and warping of the frame or cracking of the masonry. Typical details for window and door framing are shown in figures 17, 18, 19 and 20.

6t. Modular design

Concrete masonry should be of modular design based on a 4-in. module. The module should preferably be 8 in. but a 4-in. module may be used and may simplify the determination of length of bearing under a lintel. A.S.A. standards for modular design are A62.1 - 1945 and A62.3 - 1946.

6u. Drainage of walls

In cavity walls, the bottom of the cavity should be kept clear of mortar droppings during construction. Flashings and weep holes should be placed at the bottom and over openings of cavity walls (Figure 16). Flashings should extend over the full length of lintels and over bond beams and solid sections of the wall below the top course. Flashings should be made from hot-rolled copper sheet of 10 oz. weight having a thickness of 0.013 to 0.017 in., inclusive. The copper sheets should comply with the requirements of Federal Specification QQ-C-576. The flashing strips should be lapped 3 in. at the ends. The laps should be filled and sealed with bituminous plastic cement meeting the requirements of Federal Specification SS-C-153, type 1. Weep holes should be placed at the bottom of vertical joints over flashings at intervals not exceeding 32 in. The area of the weep holes should not be smaller than that of 3/8 in. in diameter holes. The weep holes may be formed by the use of rubber tubing, withdrawn after the wall is completed.

7. ERECTION

7a. Bracing to resist lateral loads

Masonry walls in locations where they may be exposed to high winds during erection should not be built higher than 10 times their thickness unless adequately braced or until provision is made for the prompt installation of permanent bracing at the floor or roof level immediately above the story under construction. Back fill should not be placed against foundation walls until they have been braced to withstand the horizontal pressure.

7b. Wetting of masonry units

Concrete masonry units should not be wetted before laying and their moisture content should not exceed that specified in Section 3d.

7c. Joint reinforcement

Joint reinforcement which has been bent or damaged in handling should not be used until after it has been straightened and placed in good condition.

7d. Protection against freezing

Masonry should be protected against freezing for at least 48 hrs. after being laid. Unless adequate precautions against freezing are taken, no masonry should be laid when the temperature is below 32°F on a rising temperature, or below 40°F on a falling temperature, at the point where the work is in progress. The laying of masonry should not proceed on frozen material.

7e. Cleaning

At the conclusion of the masonry work, mortar projecting from the wall faces should be cut away. All scaffolding equipment, surplus materials and debris should be removed from the finished structure.

8. PAINTING

Portland cement-water paints or grouts should be used as base coats on the exterior faces of all above-grade concrete-masonry walls that are to be painted. The grouts should be used on rough-textured masonry surfaces and the paints should be used on smooth surfaces. The base coats may be applied at any suitable time after completion of the walls. There are certain advantages in favor of early and of late applications. An early application tends to protect the masonry against saturation by heavy and long continued wind-driven rains, thereby preventing an immediate moisture expansion and a later shrinkage of the masonry. A late application tends to seal and fill shrinkage cracks which have developed in the masonry since its completion. Pneumatically applied coatings of suitable cementitious materials may be used as alternate base coats instead of portland cement paints and grouts, see section 8d.

8a. Base coats on rough-textured walls

Portland cement grouts used as base coats on rough-textured walls should be either of the two kinds listed below:

(1) Job mixed grout containing 40 to 50 percent of either white or gray portland cement and 60 to 50 percent of a suitable sand aggregate. The sand aggregate should pass a No. 20 sieve and should otherwise be suitable for use as a concrete or masonry mortar aggregate.

(2) A paint meeting the requirements of Federal Specification TT-P-21, type II, class B.

8b. Base coats on smooth-textured walls

Portland cement paints used as base coats on smooth-textured walls should be either of the two kinds listed below:

(1) Either white or gray portland cement.

(2) A paint meeting the requirements of Federal Specification TT-P-21, type II, class A.

8c. Application of base coats

Before applying the base coat, the masonry should be clean, and all cracks or openings in the wall facing that are larger than 1/16 in. in width or diameter should be filled with mortar or grout. The masonry should have been wetted and should be in a damp condition but without water showing on the surface at the time the base coat is applied. Paints and grouts should be applied by vigorous scrubbing with brushes having stiff-fiber bristles. The base coat should be cured by light wetting at least twice per day for two days after application. In general, application of the base coats should follow the recommendations in ACI Standard 616-49 (reprint title 46.1), "Recommended Practice for the Application of Portland Cement Paint to Concrete Surfaces."

8d. Pneumatically applied cementitious base coats

An optional method of applying a cementitious base coat in lieu of that specified above may be selected by the contractor. This consists of coating the surfaces with a mortar consisting of portland cement, a water-repellent admixture, and selected aggregates (excluding soft aggregates), applied pneumatically by spray in one continuous operation to a minimum thickness of 1/8 in. beyond the nominal face of the wall. Application shall be by a firm specializing in this type of coating. Specifications for similar but thicker cementitious facings are given in ACI Standard 805-51, "Recommended Practice for the Application of Mortar by Pneumatic Pressure." (ACI Reprint Title 47-48).

8e. Finish coats

Finish coats should be of cement-water paint and should be applied after the base coat has hardened. The base coat provides protection against the leakage of wind-driven rain, and the time of application of the finish coats should be selected so that weather conditions are suitable. The finish coats may be expected to seal fine hairline cracks and crazing in the base coats resulting from further drying of the masonry, and application of the finish coats may therefore be delayed until such drying may have occurred.

8f. Calking

Calking materials should comply with the requirements of Federal Specification TT-C-598 (gun application). Application of calking or of the stripping used as a substitute for calking should be made after the painting has been completed.

9. SAMPLING AND TESTING CONCRETE MASONRY UNITS

Except as modified herein methods of sampling and testing concrete masonry units should be in accordance with ASTM Standard C140-52.

9a. Drying shrinkage, selection of specimens

At least 10 days should be allowed for completion of the drying shrinkage tests. Five individual units should be selected from each lot of 10,000 units or fraction thereof and 10 individual units from each lot of more than 10,000 and less than 100,000 units. For lots of more than 100,000 units, 5 individual units should be selected from each 50,000 units or fraction thereof contained in the lot. Additional specimens may be taken at the discretion of the Contracting Officer. Units previously subjected to any other tests which involve their being subjected to temperatures exceeding 150°F should not be used in the drying shrinkage test. At the discretion of the Contracting Officer, bars not less than 2 in. in width and equal in length to the height of the full-sized units may be cut from the units selected for use in the drying shrinkage test.

9b. Test for drying shrinkage

The specimens should be prepared with suitable contacts for use in measuring their changes in length to the nearest 0.0001 percent. They should then be submerged in water at 73° ± 5°F for 24 hr. following which the initial length should be procured. The specimens should then be dried in a ventilated oven at 230° ± 5° F for 48 hr, after which they should be stored for at least 18 hr in a vapor-tight container at 73° ± 5° F. Their lengths should then be remeasured. The percentage drying shrinkage should be calculated as 100

$$\left(\frac{Lw-Ld}{Lw} \right)$$

where Lw = wet length and
Ld = dry length

Drying shrinkage tests on concrete masonry units are described in a progress report of ACI Committee 716, Reprint title 49-53, published in the April 1953 Journal of the American Concrete Institute.

9c. Periodical check on moisture content

Representative samples should be taken from the on-site stock piles for check of moisture content. Two such checks should be made per week during construction of the walls. Each sample should consist of at least 3 blocks. The tests should be performed in accordance with ASTM Standard C140-52 and the units should be selected from the stock piles in current use, at the time of test. Units which fail to meet the moisture content limitation should be rejected and should not be used until properly dried, see sections 3d and 3e.

9d. Staining test for aggregate

The test for staining should follow the procedure in the proposed Tentative Specifications for Lightweight Aggregate for Concrete Masonry Units (see sections 5 and 7 of the tentative specifications dated March 5, 1953, ASTM Committee C-9).

9e. Test for surface popouts

Three whole concrete masonry units or pieces of the face shells from the three concrete masonry units may be selected for the test. When pieces of the face shells are used their surface area should total at least 40 sq in. for each unit and the smallest length or width of the pieces should not be less than 3 in. The selected specimens should be autoclaved in accordance with the Standard Method of Tests for Autoclave Expansion of portland cement, ASTM designation C151. The specimens should be placed above the water in the autoclave and racked to permit the free circulation of steam around them. If the heat capacity of the specimens is greater than that of the specimens normally used in an autoclave, the time required to reach maximum pressure in the autoclave and to cool the specimens may be increased. However, the duration of exposure at maximum pressure should not be less than 2 hours. Subsequent to the autoclave exposure, visual inspection of the specimens should not disclose any surface popouts in them. Evidence of surface popouts or severe disintegration (breaking) of the specimens should result in rejection of the units they represent. This test may also be helpful in disclosing staining of the units.

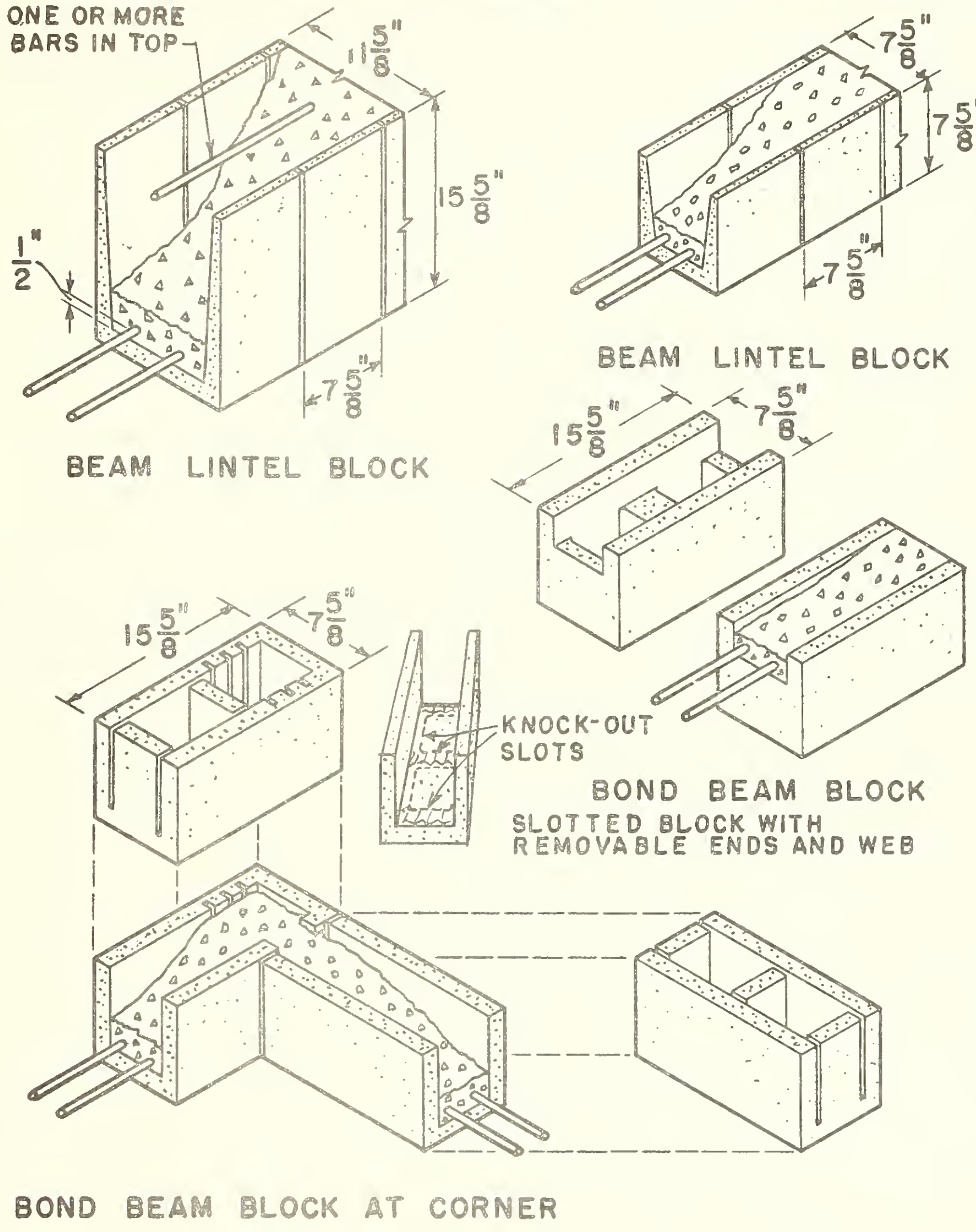
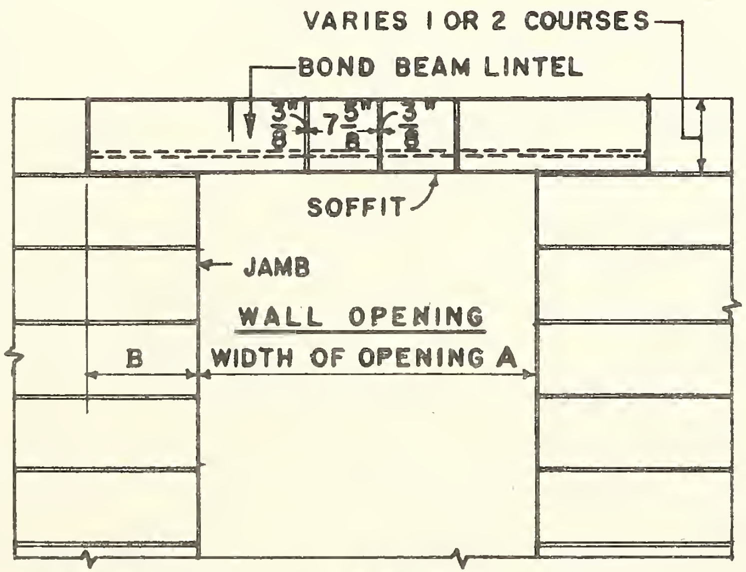


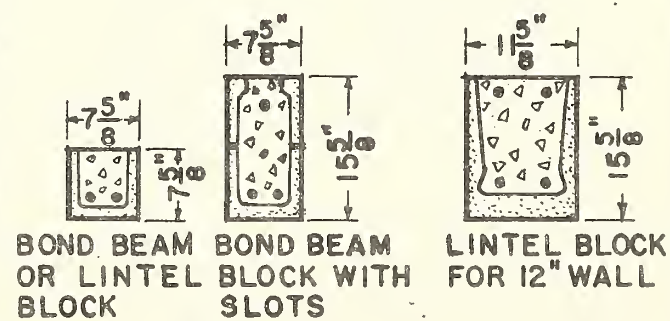
FIG. 1 TYPICAL BOND BEAM UNITS

NBS



MINIMUM LINTEL BEARING "B"	MAXIMUM OPENING WIDTH "A"
8 IN.	3 FT. OR LESS
12 IN.	NOT MORE THAN 12 FT.
16 IN.	NOT MORE THAN 16 FT.
SPECIAL DESIGN	FOR SPANS MORE THAN 16 FT.

TYPICAL LINTEL SECTIONS



NOTES

LINTEL STEEL MAY BE CONTINUED IN BOND BEAM UNITS TO FORM CONTINUOUS BOND BEAM.

BOND BEAM LINTELS SHALL BE DESIGNED FOR SHEAR AND MOMENT.

MINIMUM REINFORCEMENT SHALL CONSIST OF 2 No.4 BARS OR EQUIVALENT STEEL AREA.

FIG.2 BOND BEAM LINTELS, EXTERIOR WALL.

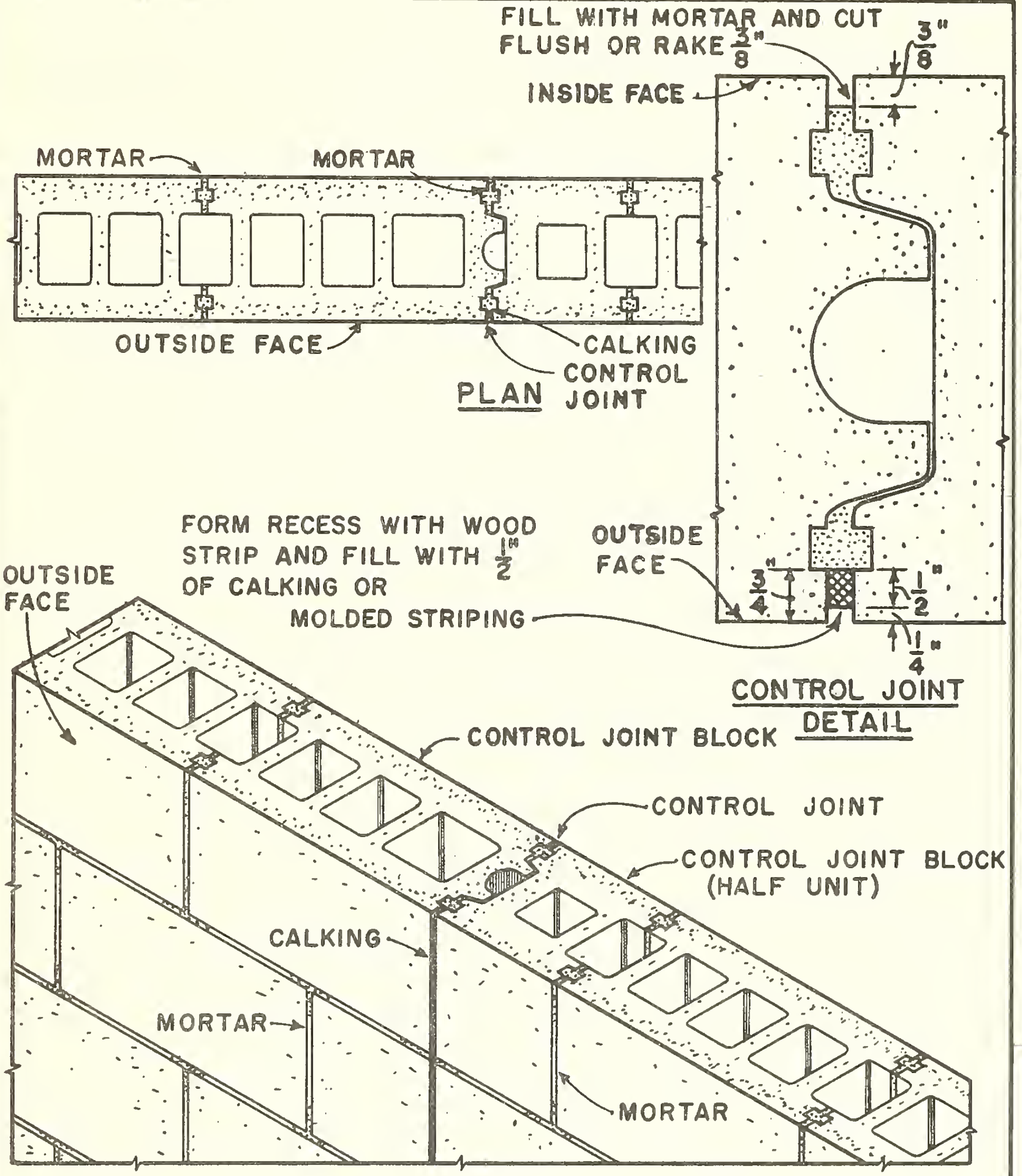


FIG. 3 SHRINKAGE CONTROL JOINT USING 3-CELL CONTROL JOINT BLOCK.

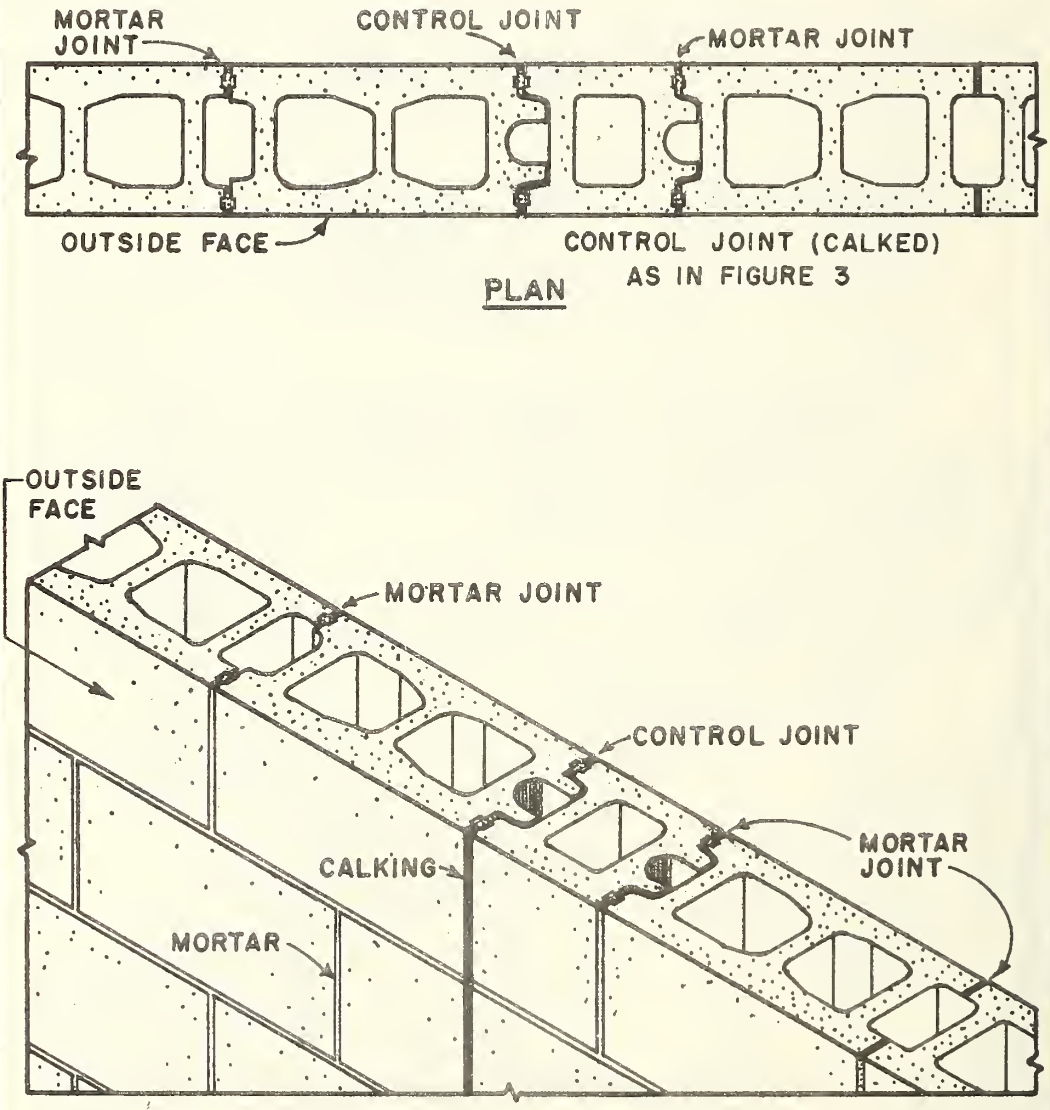


FIG. 4 SHRINKAGE CONTROL JOINT USING 2-CELL CONTROL JOINT BLOCK.

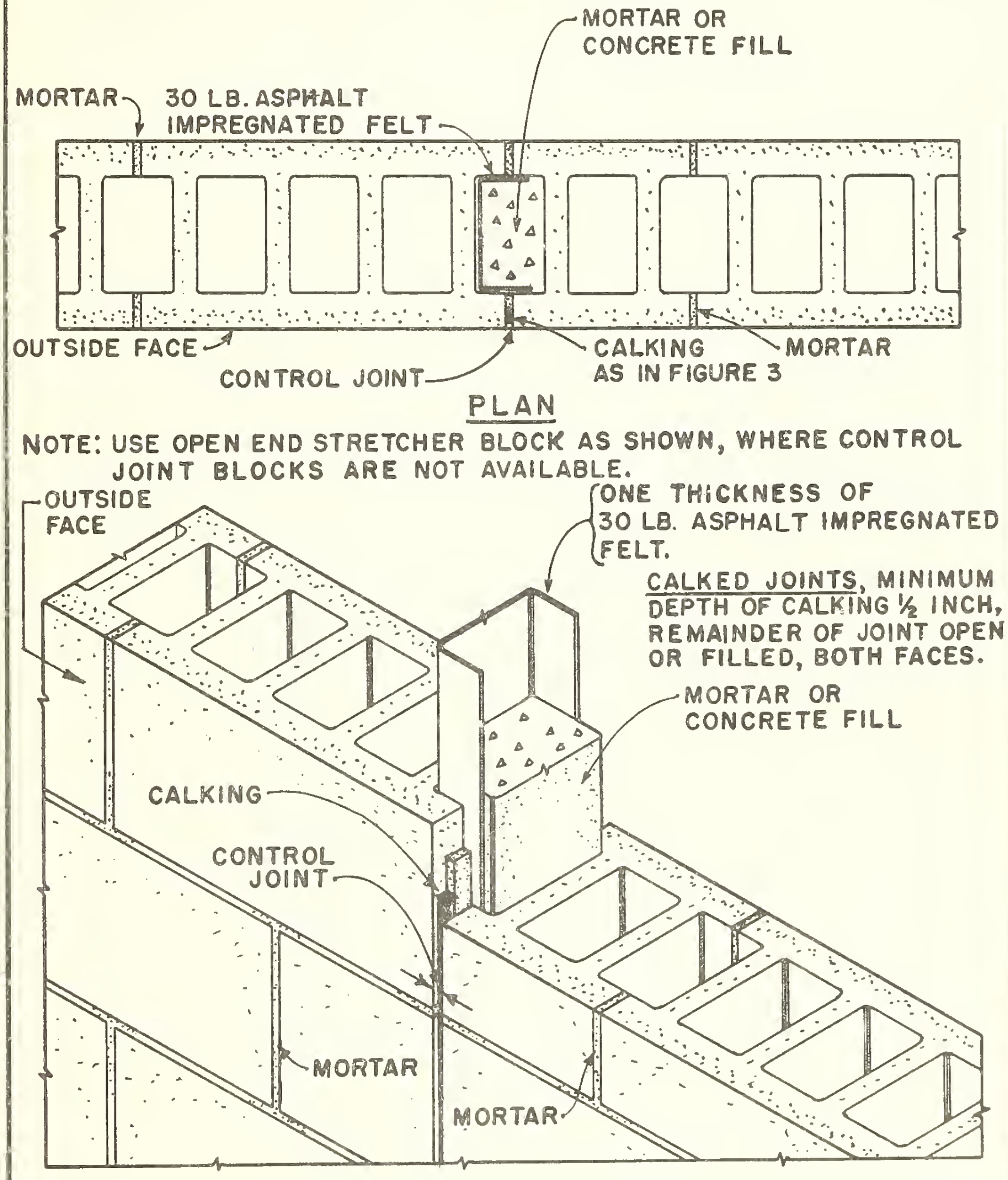


FIG. 5 SHRINKAGE CONTROL JOINT USING OPEN END STRETCHER BLOCK AND CONCRETE CORE.

NBS

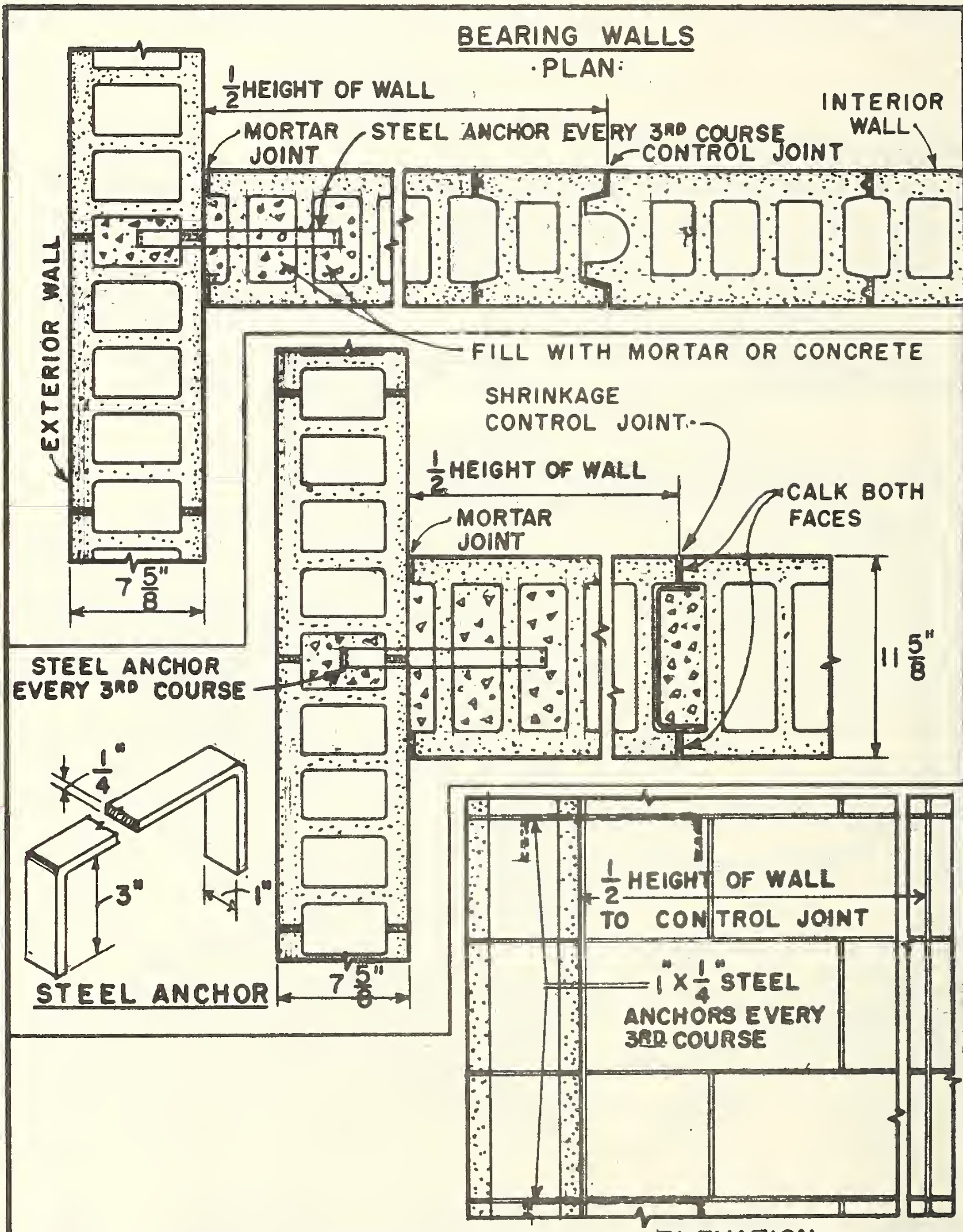


FIG. 6 WALL INTERSECTIONS

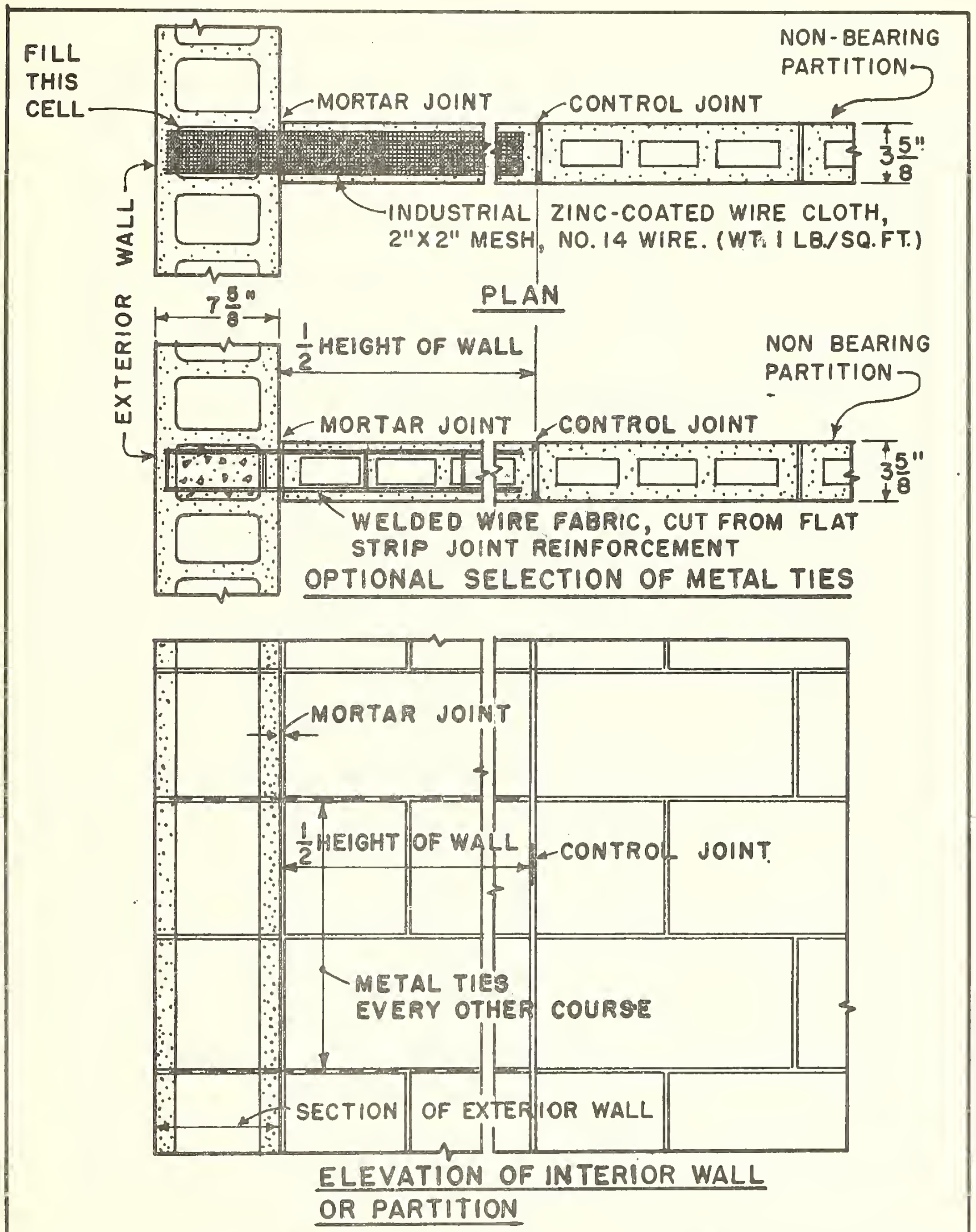


FIG. 7 TYPICAL WALL AND PARTITION INTERSECTION

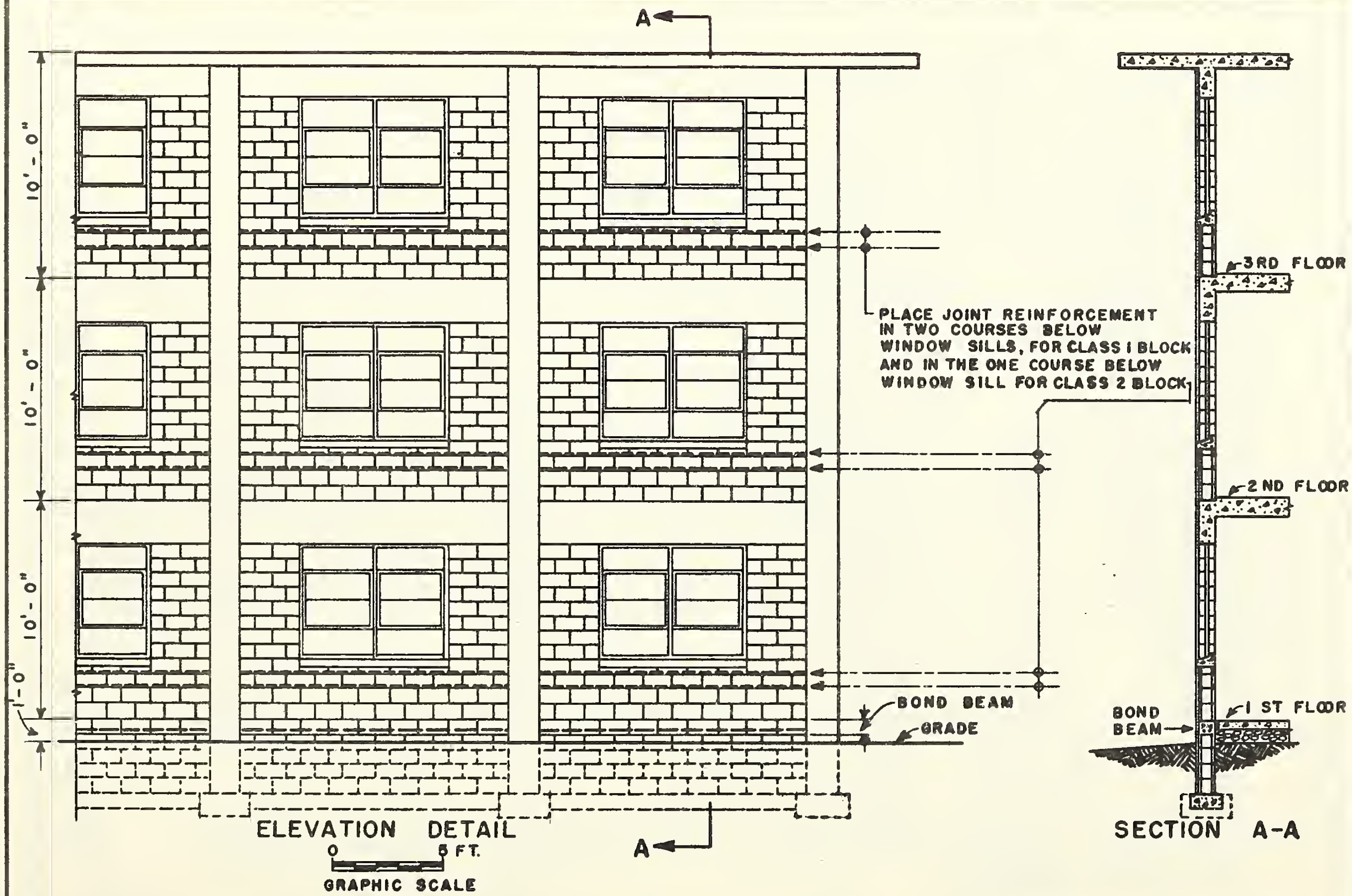


FIG. 8 ENCLOSURE WALL CONSTRUCTION

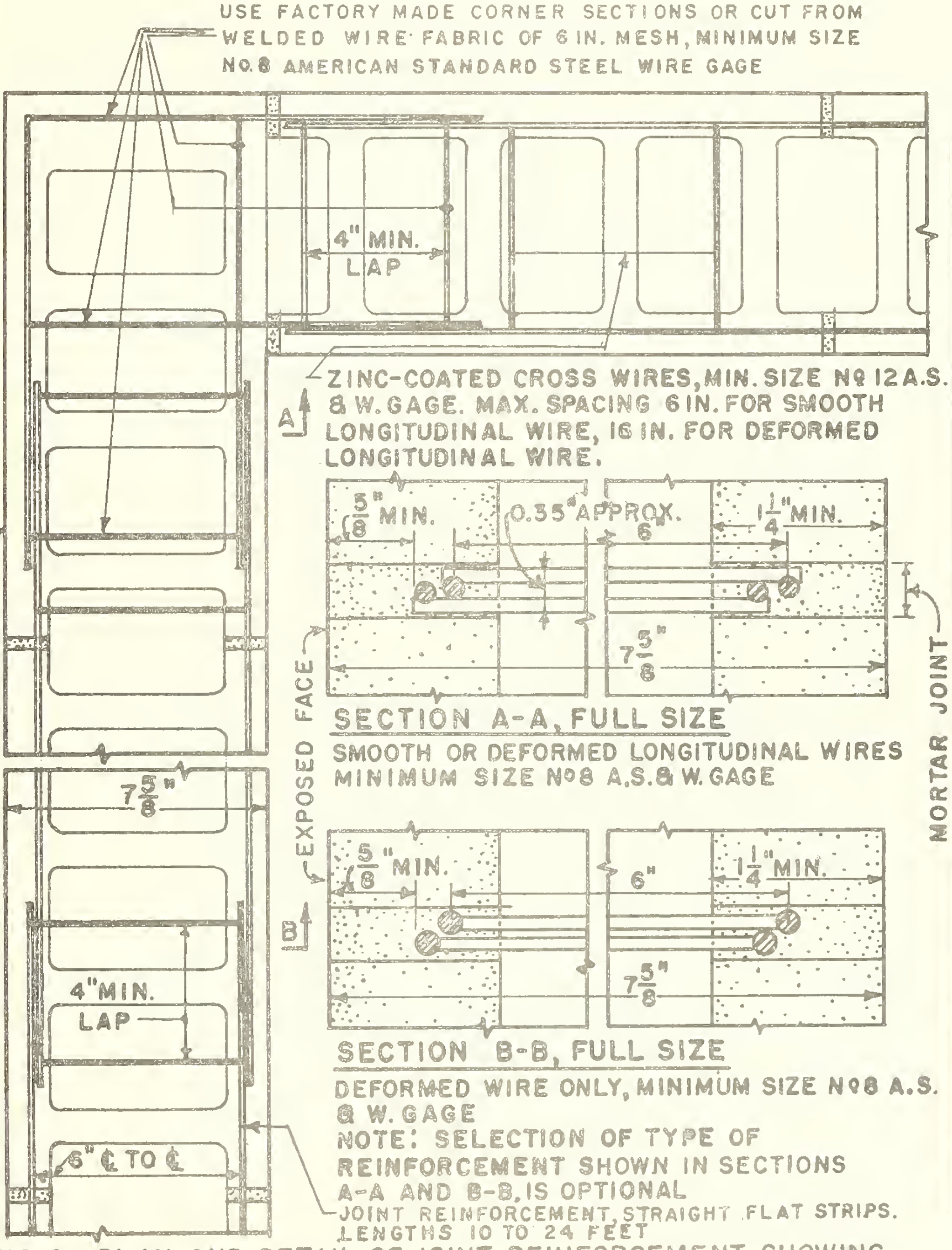
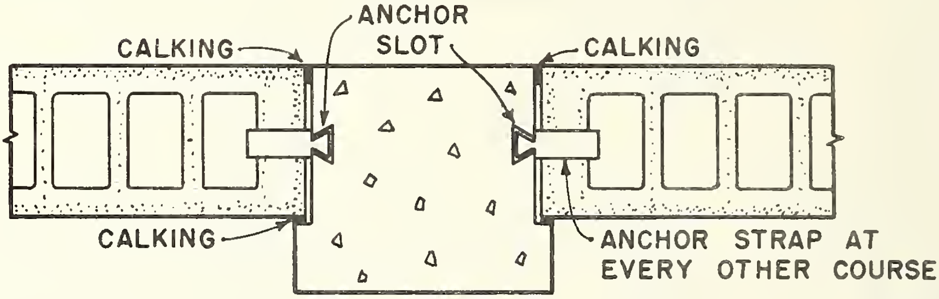
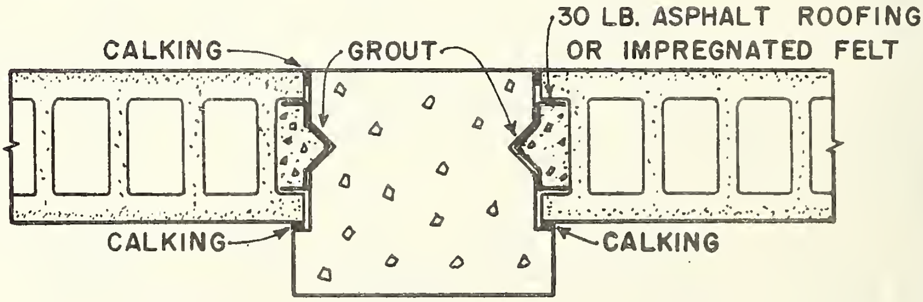


FIG. 9 PLAN AND DETAIL OF JOINT REINFORCEMENT SHOWING LAPPED SPLICES



PLAN OF REINFORCED CONCRETE COLUMN SHOWING DOVETAIL TIES.



PLAN OF REINFORCED CONCRETE COLUMN HAVING V-SHAPED DEPRESSIONS.

FIG. 10 CONCRETE FRAME, COLUMN AND WALL INTERSECTION.

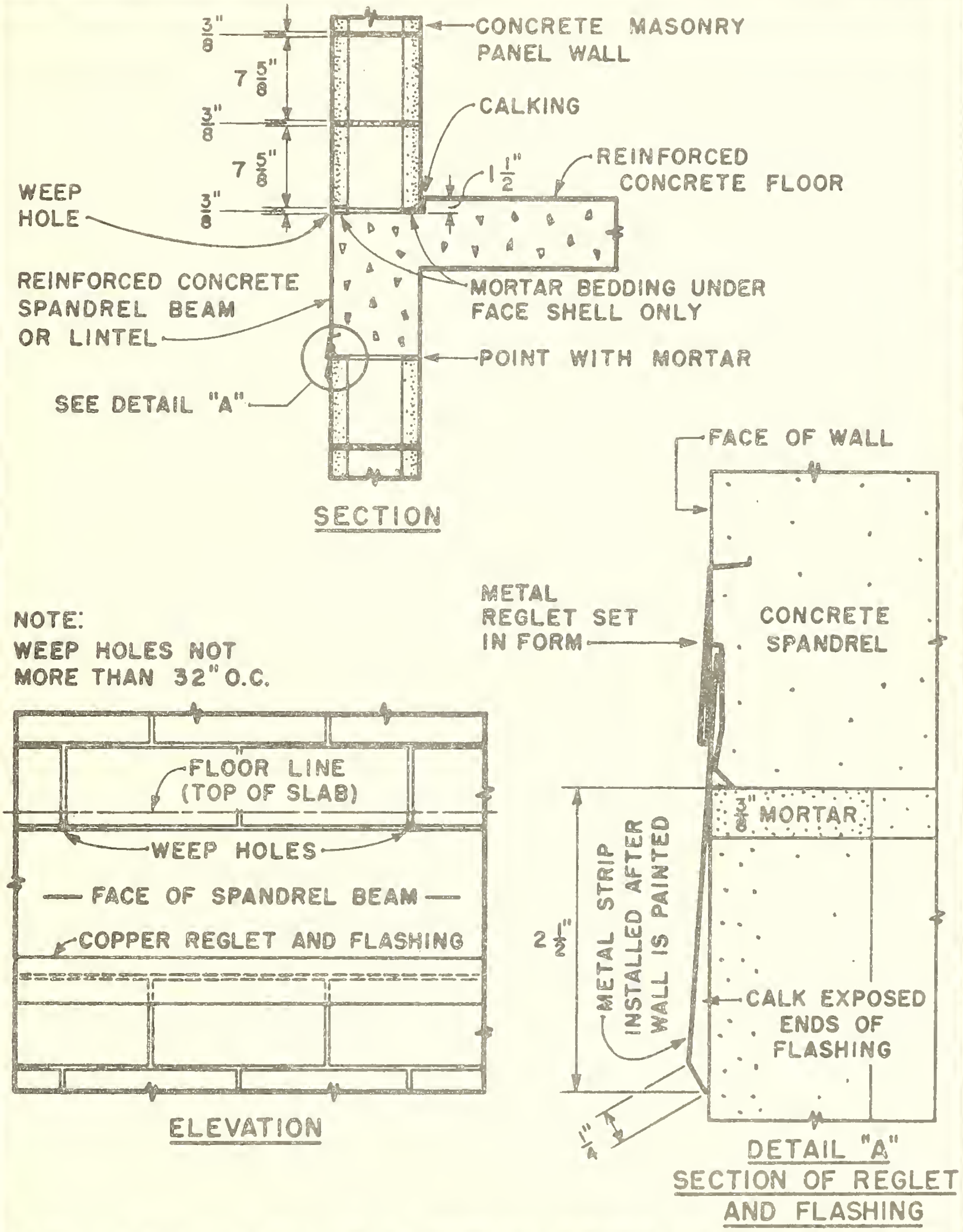


FIG. 11 PANEL WALL IN CONCRETE FRAME CONSTRUCTION.

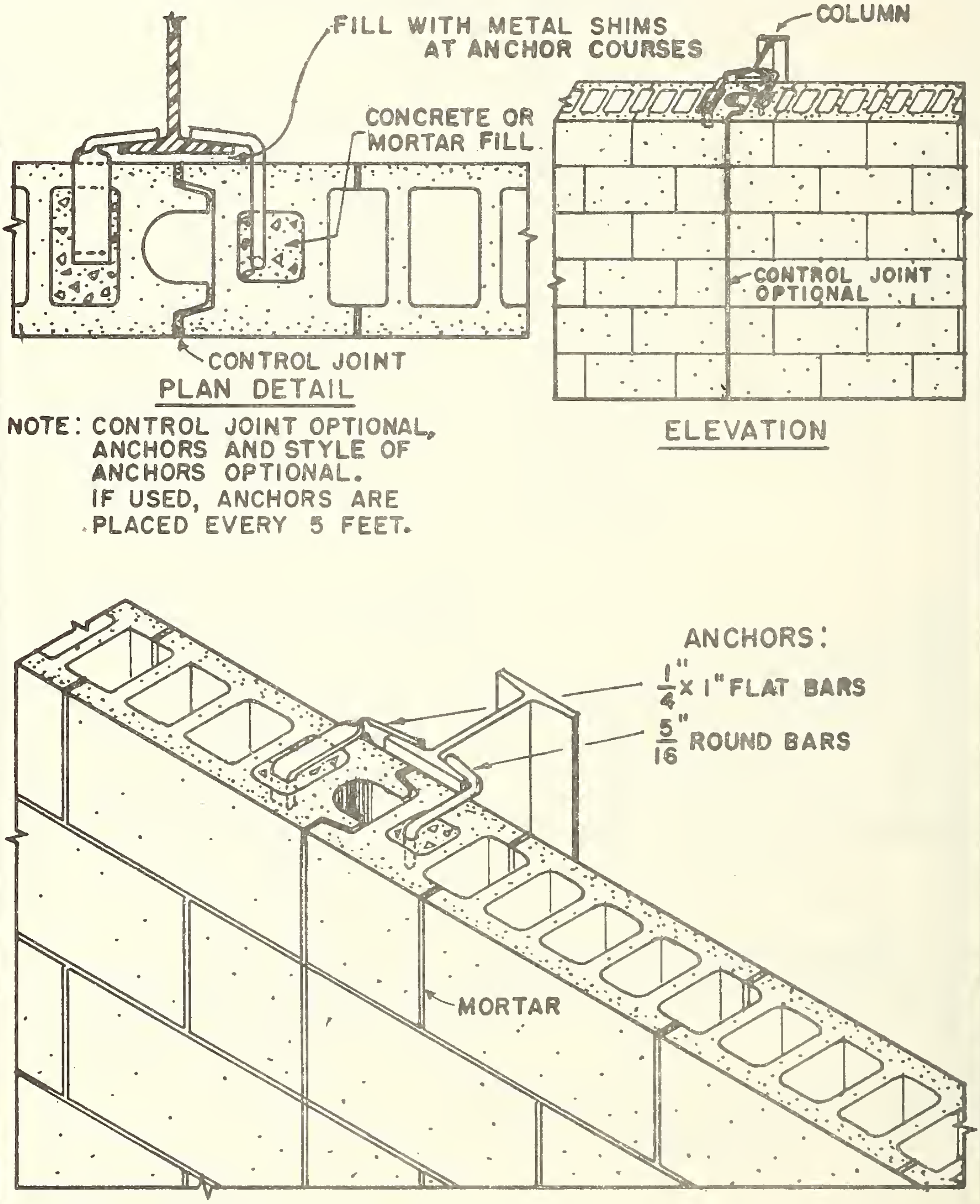
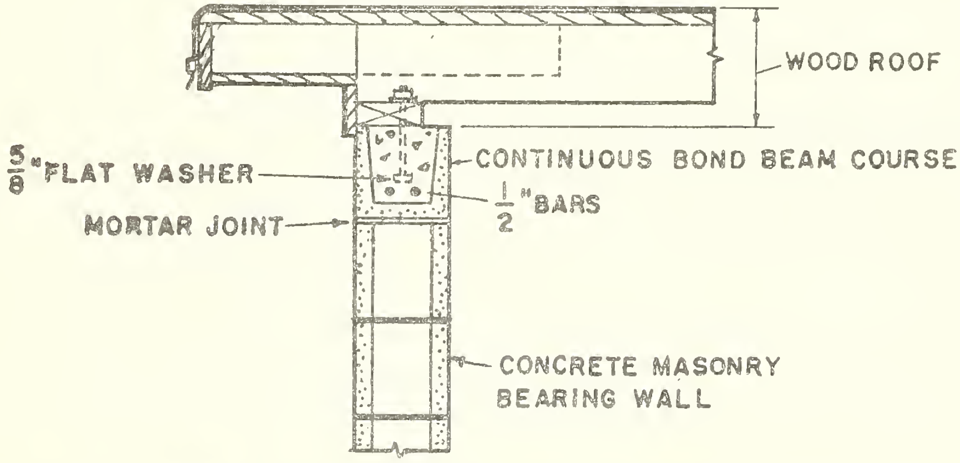
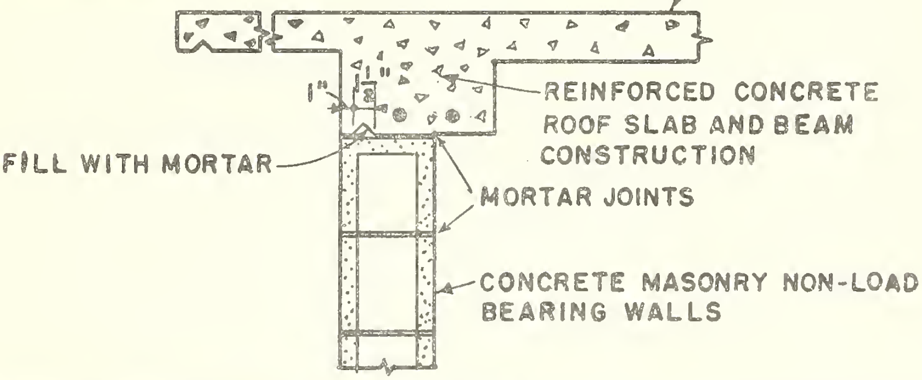


FIG. 12 TYPICAL STEEL COLUMN WALL INTERSECTION.



DETAIL OF INTERSECTION OF ROOF AND WALL OF ONE-STORY STRUCTURE HAVING BEARING WALL AND WOOD ROOF

NOTE: ROOF SHALL BE INSULATED ON TOP SURFACE



DETAIL OF INTERSECTION OF ROOF AND WALL HAVING NON-BEARING WALL STRUCTURE

FIG.13 ROOF AND WALL INTERSECTIONS

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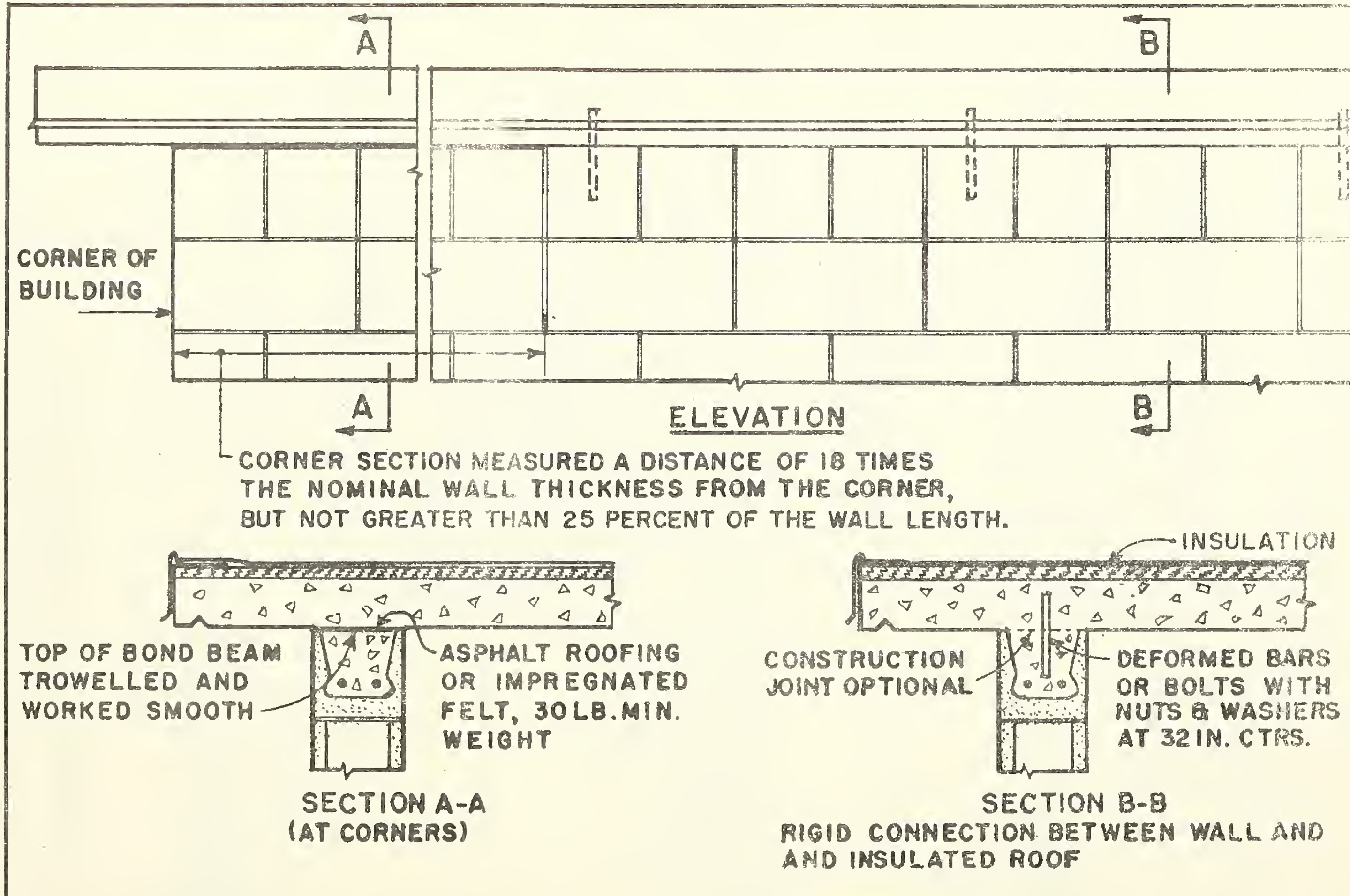

FIG. 14 INTERSECTION OF LOAD-BEARING WALL AND CONCRETE ROOF SLAB FOR BUILDINGS LESS THAN 40 FT. IN LENGTH.

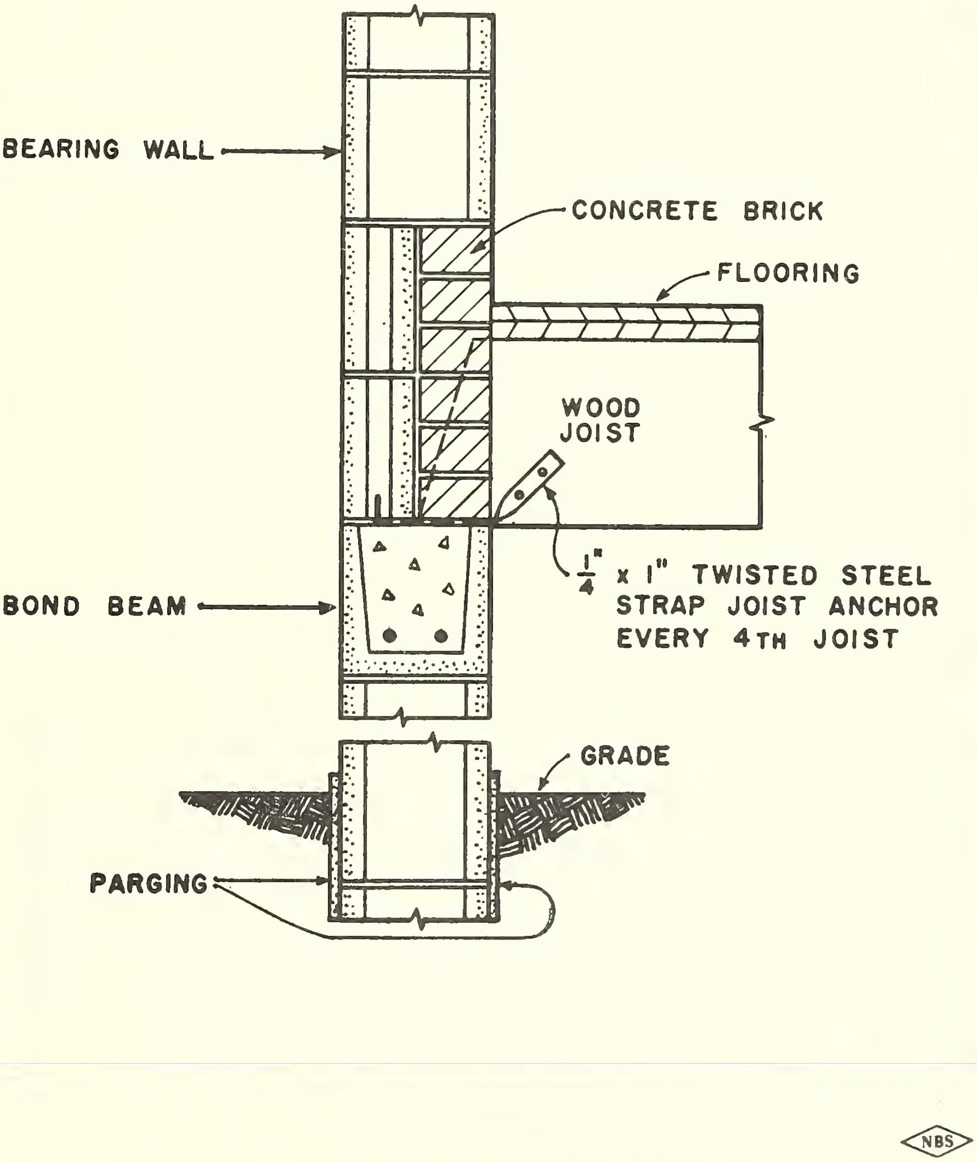

FIG.15 TYPICAL WALL SECTION AT WOOD JOIST FLOOR.

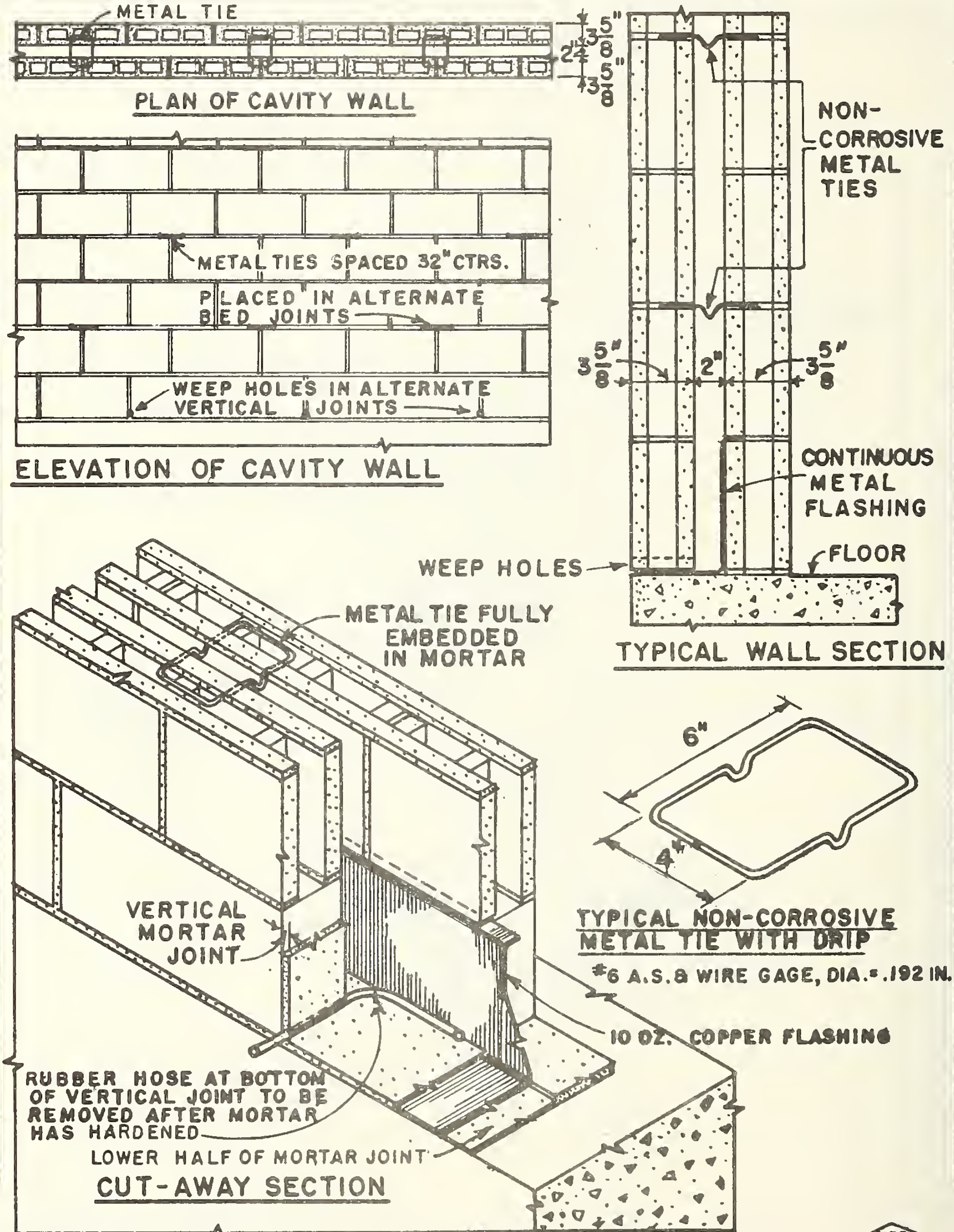

FIG.16 MASONRY CAVITY WALL

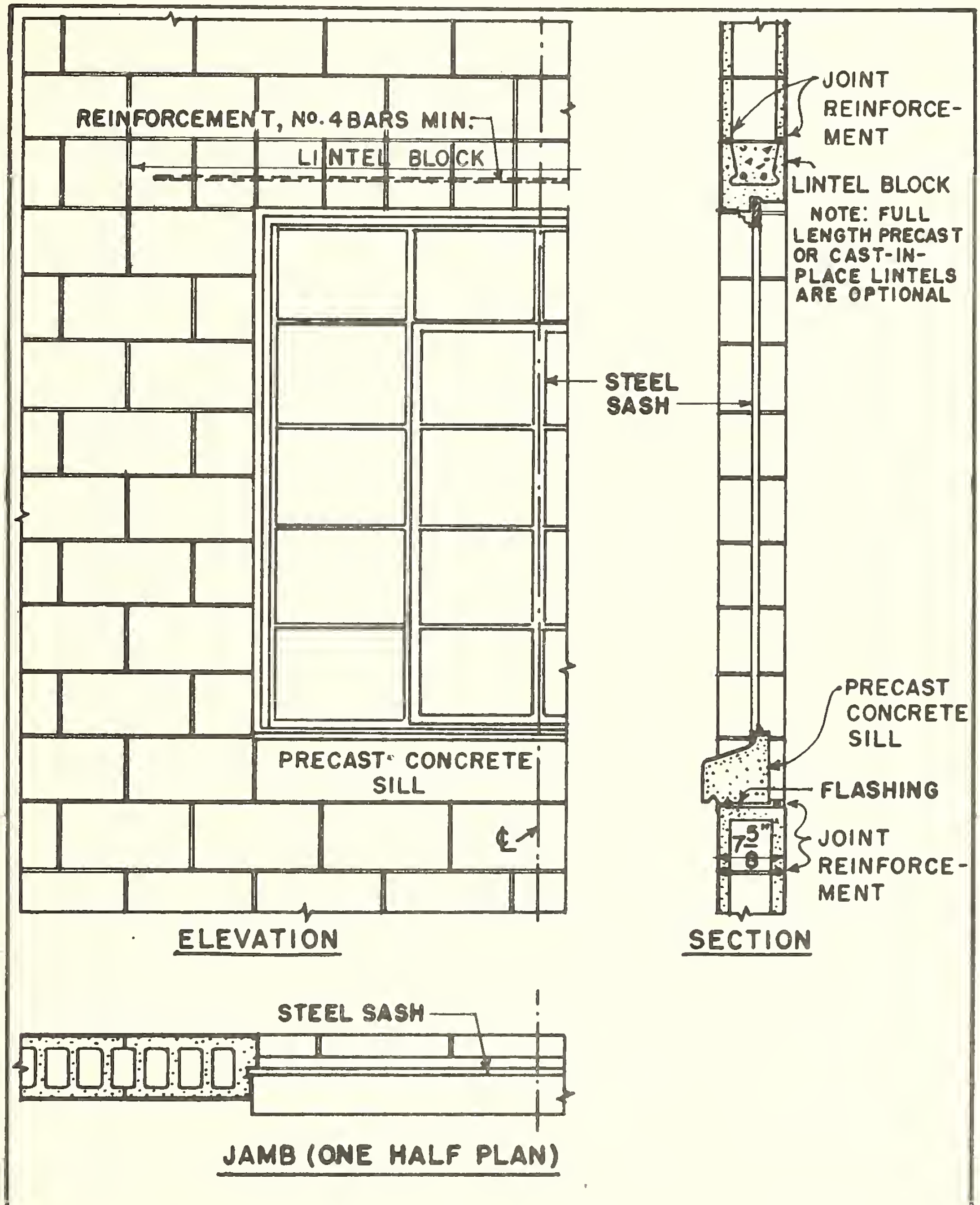

FIG. 17 TYPICAL WINDOW FRAMING, EXTERIOR

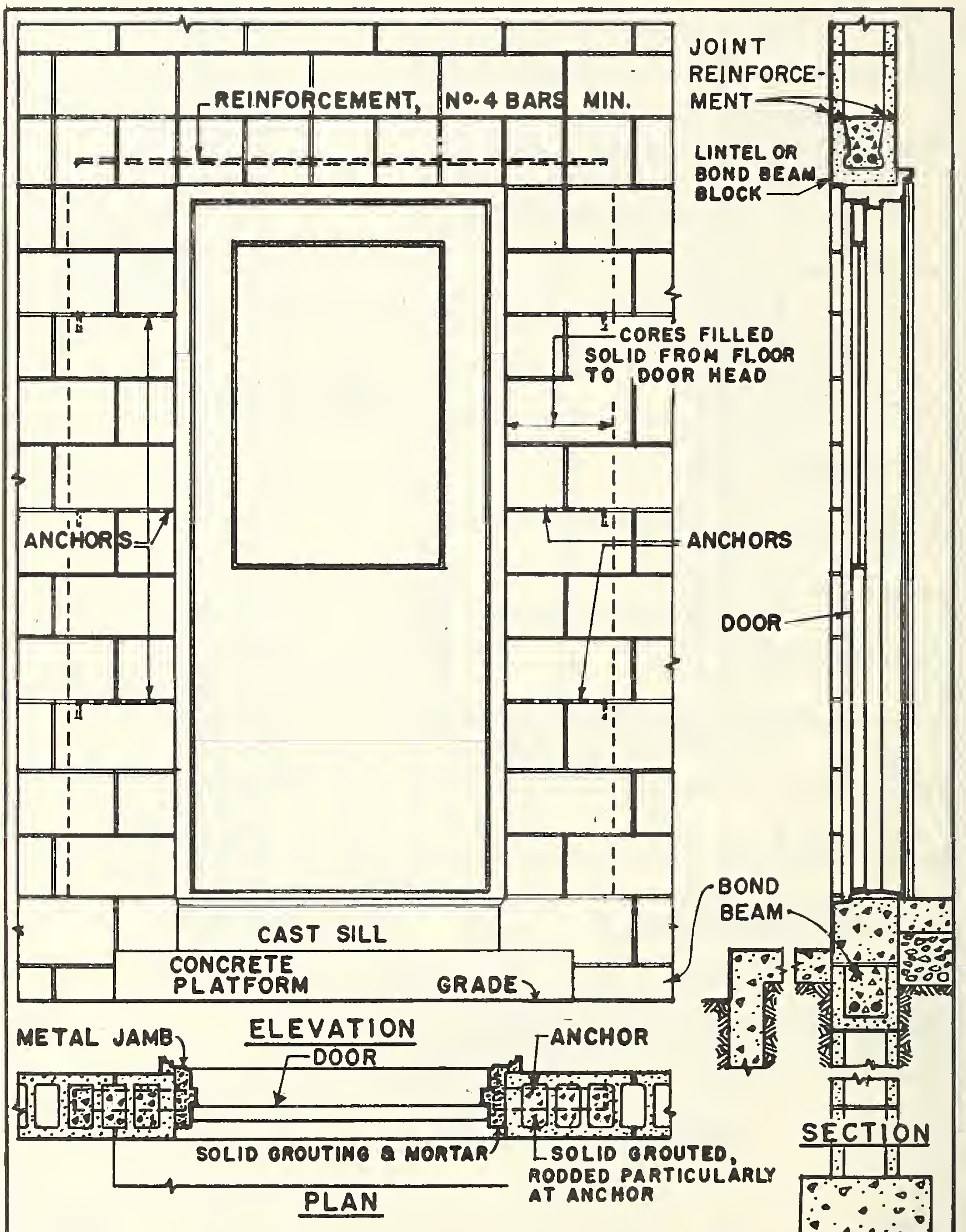

FIG. 18 TYPICAL DOOR FRAMING, EXTERIOR

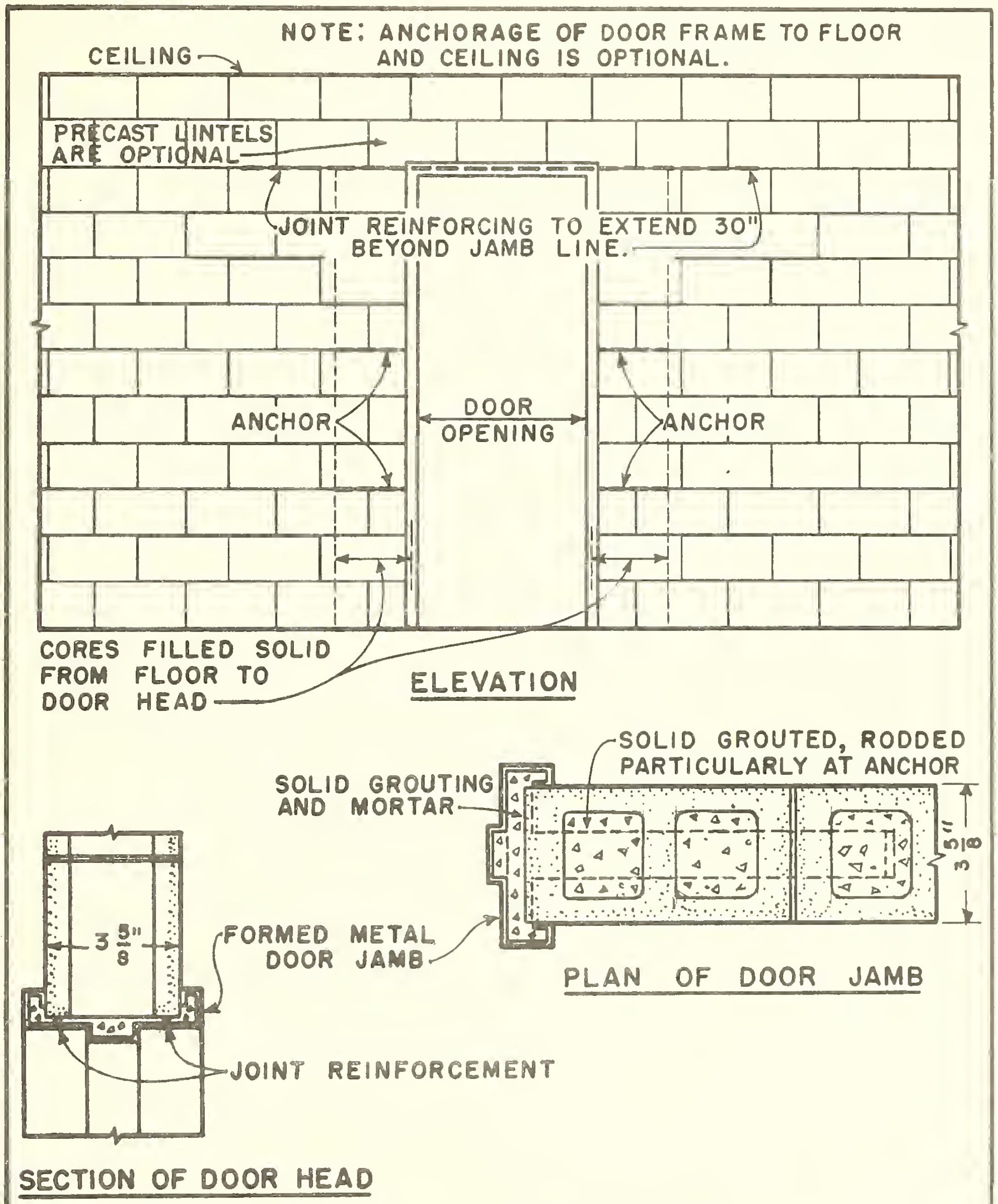

FIG. 19 DETAIL OF TYPICAL METAL DOOR FRAME IN PARTITION.

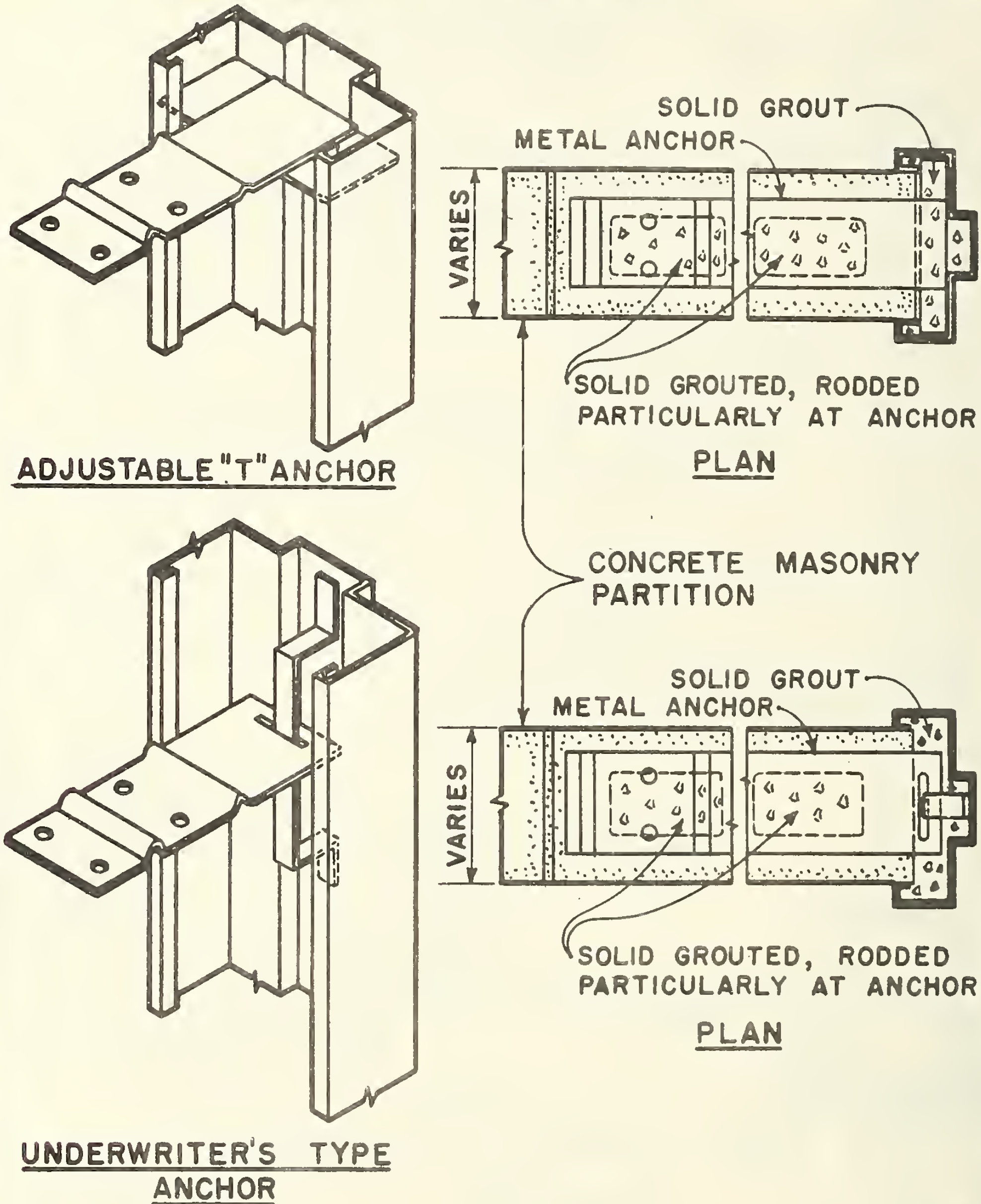

FIG. 20 OPTIONAL TYPES OF TYPICAL JAMB ANCHORS FOR METAL DOOR FRAMES IN INTERIOR PARTITIONS.

THE NATIONAL BUREAU OF STANDARDS

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