Technical Notes 24G - The Contemporary Bearing Wall - Detailing
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INTRODUCTION

The selection of a wall type and appropriate connection details is one of the most important decisions to be made in the design of a bearing wall building. In most cases, the primary consideration will be a system which satisfies the structural requirements of the building. Other considerations are also of importance, including the properties and performance of the walls and floors that will result in an economical, maintenance-free and easy-to-construct building.

Bearing walls offer the designer the opportunity to develop a complete building system in which the floors and walls not only carry the vertical and lateral loads, but also provide separation, thermal and acoustical control, and fire-resistive and low maintenance construction.

MATERIALS

Materials used in constructing the walls for bearing wall buildings will have considerable influence on the satisfactory performance of the structure. In most cases, the compressive stresses will be relatively high, requiring medium to high strength masonry units and mortar. Materials selected should comply with the requirements contained in the standard, *Building Code Requirements for Engineered Brick Masonry,* BIA, 1969.

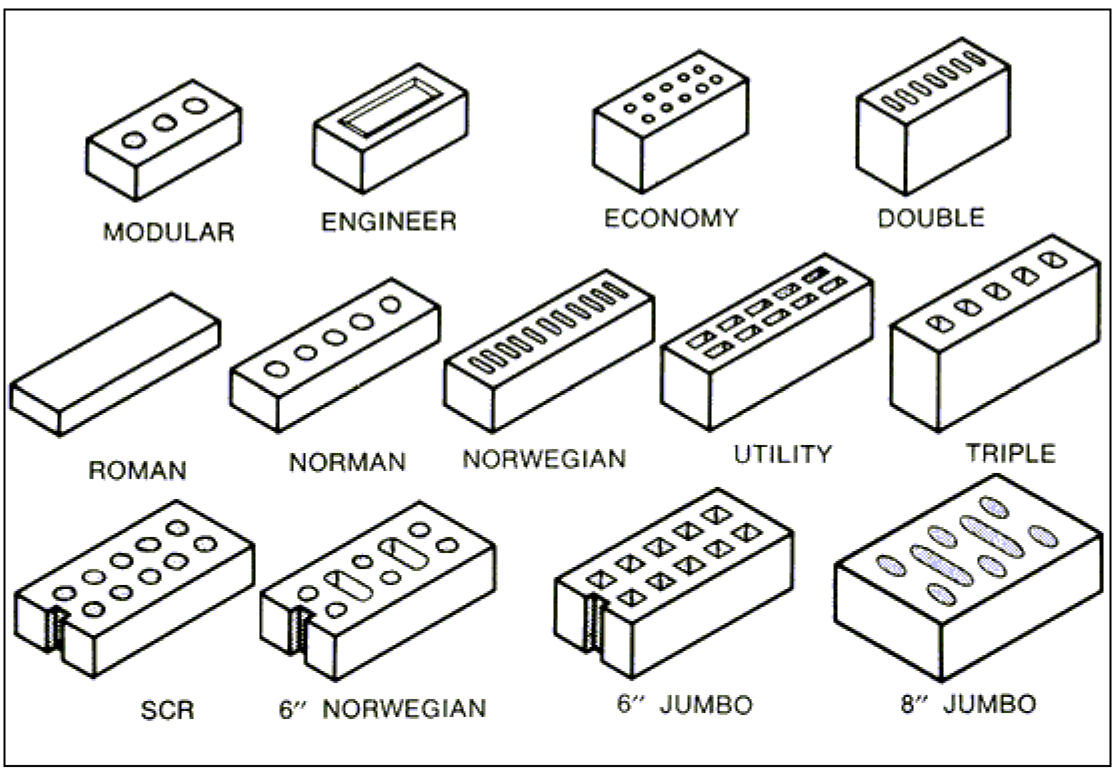
Brick. A large percentage of the brick produced in the United States have unit compressive strengths in excess of 5000 psi, with some having compressive strengths as high as 25,000 psi. Units are readily available throughout the U.S. and Canada which have strengths of 10,000 psi and above. Esthetics, durability and economy should also be considered in the selection of a particular type of brick unit for a given bearing wall building. The two sizes of brick most widely used are often referred to as Standard (actual dimensions - 3-3/4 by 2-1/4 by 8 in.) and Standard Modular (actual dimensions for 3/8-in. joint 3-5/8 by 2-1/4 by 7-5/8 in.). There are many different sizes of brick made to suit local conditions. In some areas of the U.S., 3-in. bed depth brick are widely used. The sizes vary with the manufacturer and locality. The size that is most widely made and distributed is called King size, with actual bed dimensions of 3 by 9-5/8 in. and height of 2-5/8 in. (laying 4 courses to 12 in.) or 2-3/4 in. (laying 5 courses to 16 in.). Walls built with larger brick units usually provide greater economy than walls of smaller units. Table 1 lists a number of modular brick sizes. These are illustrated in Fig. 1. The local availability and strength of specific units should be ascertained prior to the design.

TABLE 1
Nominal Modular Sizes of Brick

Unit Designation	Dimensions			
	Thickness	Height	Length	Modular Coursing
Standard Modular	4"	2 - 2/3 "	8"	3C = 8 "
Engineer	4"	3 - 1/5 "	8"	5C = 16 "
Economy	4"	4"	8"	1C = 4 "
Double	4"	5 - 1/3 "	8"	3C = 16 "
Roman	4"	2"	12"	2C = 4 "
Norman	4"	2 - 2/3 "	12"	3C = 8 "
Norwegian	4"	3 - 1/5 "	12"	5C = 16 "
Utility [1]	4"	4"	12"	1C = 4 "
Triple	4"	5 - 1/3 "	12"	3C = 16 "
SCR brick [2]	6"	2 - 2/3 "	12"	3C = 8 "
6" Norwegian	6"	3 - 1/5 "	12"	5C = 16 "
6" Jumbo	6"	4"	12"	1C = 4 "
8" Jumbo	8"	4"	12"	1C = 4 "

[1]Also called Norman Economy, General and King Norman.

[2]Reg. U.S. Pat. Off., SCPI.



Typical Modular Brick

FIG. 1

Mortar. There is no one mortar that is best for all purposes. Masonry mortar should be selected for the particular use. ASTM Specifications C 270, "Mortar for Unit Masonry", are recommended as a basis for mortar specifications. It is further recommended that the Proportion Specification be used rather than the Property Specification and that mortar be constituted of portland cement (type I, II or III), type S hydrated lime (non-air-entrained), or lime putty and sand.

Building Code Requirements for Engineered Brick Masonry recognizes three mortar types: Types M, S and N. In general, type S mortar provides high bond and compressive strength with long durability and good workability. Type N is a mortar with good strength properties, durability and excellent workability. In most cases, either type S or N mortar will provide the desirable properties for loadbearing buildings. When high compressive stresses control the design, type M mortar may be required. Type S mortar is proportioned 1C:1/2 L:4 - 1/2 S, type N mortar is 1C:1L:6S and type M is 1C: 1/4 L:3S. See *Technical Notes* 8 Revised, Portland Cement-Lime Mortars for Brick Masonry".

Metal Ties and Joint Reinforcement. In years past, structural bonding of masonry walls was generally accomplished by overlapping masonry units. In so doing, various visual patterns were created; two traditional ones being English and Flemish bond.

In the construction of the thinner masonry walls of today, when these patterns are not required by esthetic considerations, it is recommended that metal-tie bonding be used for multi-wythe solid walls in lieu of masonry bonding. Laboratory tests at the Structural Clay Products Institute and independent laboratories indicate that metal-tied walls are comparable to masonry-bonded walls in resisting compressive and transverse loads, as well as water transmission, when the collar joint is full of mortar. In addition, metal-tied walls generally cost slightly less than masonry-bonded walls. They also provide greater freedom in construction and pattern selection.

Metal ties used in bonding masonry walls should be equal to those required for cavity walls; i.e., 3/16-in. diameter steel or metal ties of equivalent strength spaced so that at least one tie is provided for every 4-1/2 sq ft of wall area. Distance between ties should not be over 24 in. vertically and 36 in. horizontally. Metal ties should be of corrosion-resistant metal or protected with a corrosion-resistant metal. Ties may be shaped to form a Z, rectangle or continuous tie of either the ladder or truss type. In cavity wall construction, the Z and rectangular ties, which are often used, have depressions or drips in the middle of the ties. The drip is not necessary and reduces the strength of the tie; however, most of the ties on the market have sufficient strength with or without the drips. There are some advantages to the continuous ladder or truss type joint reinforcement, particularly where wythes are made of units with different physical properties or in wall areas subject to stress concentration.

If stack bond masonry is used as a bearing wall, continuous joint reinforcement should be provided, spaced not more than 16 in. on center vertically, one 9-gage or larger longitudinal wire for each 6 in. of wall thickness or portion thereof.

CONSTRUCTION DETAILS

Even though the masonry details must be handled somewhat differently in bearing wall buildings than in structural frame buildings, the same major considerations are prevalent:

1. Structural requirements of the buildings must be met. Anchorage must be provided which will transmit stress where desired. Equally important are anchorage details which will not transmit unwanted forces.

2. Since the elements of the building are in a constant state of motion, such movement must be accommodated or distress will occur.

3. The opportunity for uncontrolled entrance or condensation of water must be avoided. The problem of keeping water out of the bearing wall building may be solved by using cavity or grouted walls. Where solid walls are used with or without furring, pargeting, waterproofing and systems of flashing and drainage can be provided. See *Technical Notes* 7A Revised, Water Resistance of Brick Masonry-Materials", and 7B Revised, "Water Resistance of Brick Masonry-Construction and Workmanship".

Structural Requirements. Because of their structural simplicity, it is possible to design loadbearing clay masonry buildings quite easily, using accepted theories. In some buildings, the floor plan will be such that the longitudinal exterior and corridor walls may be loadbearing. In others, it may be more advantageous to have transverse bearing walls. In both cases, horizontal forces are usually resisted by shear wall action. Since the transverse strength of non-reinforced masonry walls is relatively low, structural positioning of building parts are so arranged as to minimize this action and to exploit the compressive and shear resistance of the walls.

By utilizing the floors and roof as horizontal diaphragms and the shear walls as vertical diaphragms, the horizontal forces are carried down into the foundation. Shearing stresses in bearing wall buildings will seldom control the wall type and thickness. Although flexural stresses in shear walls may control the design under certain conditions, it is the bearing stress that will generally govern. For additional information pertaining to structural design, see *Technical Notes* 24 Series, "The Contemporary Bearing Wall".

Types of walls and floors used with bearing wall construction will depend on a number of factors, including economics, climate, building type, height and arrangement of walls, and the structural requirements. In most cases, clay masonry walls from 4 to 12 in. in thickness will satisfy the structural requirements.

In developing construction details for bearing wall buildings, it is important to understand the potential condition of stress at junctures of horizontal and vertical elements. At connections, as a result of vertical and horizontal loads, compression, tension and shear may occur. Seldom is it desirable to transmit bending moments at junctures of floors and walls unless the walls are of reinforced masonry. It is relatively easy to develop details which will transmit tension and compression, as well as shear. Often, however, it is desired to transmit tension and compression alone, or shear alone. At times, it is desirable to take loads horizontally (produced by wind) but not vertically (due to gravity). For these reasons, it is important for the structural designer to take an active part in developing the construction details for a particular project.

Where concentrated loads are imposed upon masonry walls, it is recommended that bearing pads be used to distribute the stress and to permit slight movement which may occur. Suitable materials for this use include 55-lb roofing felt, pads of Neoprene, tempered Masonite or vinyl floor tile. It is advisable to design the connection so as to position the resultant of the bearing stress in the middle two-thirds of the wall. If the vertical load develops an eccentricity which falls outside of the middle two-thirds of the wall, the possibility of excessive tensile bending stresses developing in the wall must be investigated. See detailed design requirements contained in the *Building Code Requirements for Engineered Brick Masonry.*

Small amounts of reinforcing steel may be grouted in brick walls to provide extra strength. The designer may find it helpful to use steel in piers where loads are high. Bond beams are often desirable to distribute loads at floor levels. For information on the design and construction of reinforced brick masonry (RBM), see *Technical Notes* 17 series, "Reinforced Brick Masonry".

Rigid anchorage of concrete floors to the masonry walls is seldom desired or needed. The friction will often meet the structural requirements. Coefficients of friction between various materials in a dry state will vary. Standard references indicate a range of values given in Table 2. In this table, masonry may be considered to be clay, stone or concrete.

TABLE 2
Coefficients of Static Friction

Masonry and masonry	0.65 - 0.75
Masonry and concrete	0.65 - 0.75
Masonry and dry earth	0.40 - 0.60
Masonry and metal	0.25 - 0.60
Wood and wood	0.30 - 0.60
Wood and masonry	0.50 - 0.60
Wood and metal	0.40 - 0.60
Metal and metal	0.15 - 0.25

Differential Movement. All elements and materials which go into the makeup of the building are in a constant state of motion. All building materials move with changes in temperature, some move with changes in moisture content, some have plastic flow due to stress, and all have elastic deformation due to imposed loads. Provisions must be made to permit the various materials and elements to move so as not to distress any part. See *Technical Notes*, 18 series, "Differential Movement".

The stress developed in restrained elements due to a change in temperature is equal to the modulus of elasticity multiplied by the coefficient of expansion and by the change in temperature. Table 3 lists coefficients of lineal thermal expansion for many commonly used building materials.

TABLE 3
Thermal Movement

Material	Average Coefficient of Lineal Thermal Expansion, in Millionths (0.000001) per degree Fahrenheit	Thermal Expansion, inches per 100 feet for 100 F temperature increase (to closest 1/16 inch)	
Clay Masonry			
Clay or shale brick	3.6	0.43	(7/16)
Fire clay brick or tile	2.5	0.30	(5/16)
Clay or shale tile	3.3	0.40	(3/8)
Concrete Masonry			
Dense aggregate	5.2	0.62	(5/8)
Cinder aggregate	3.1	0.37	(3/8)
Expanded-shale aggregate	4.3	0.52	(1/2)
Expanded-slag aggregate	4.6	0.55	(9/16)
Pumice aggregate	4.1	0.49	(1/2)
Stone			
Granite	4.7	0.56	(9/16)
Limestone	4.4	0.53	(1/2)
Marble	7.3	0.88	(7/8)
Concrete			
Gravel aggregate	6.0	0.72	(3/4)
Lightweight, structural	4.5	0.54	(9/16)
Metal			
Aluminum	12.8	1.54	(1-9/16)
Bronze	10.1	1.21	(1-3/16)
Stainless steel	9.6	1.15	(1-1/8)
Structural steel	6.7	0.8	(13/16)
Wood, Parallel to Fiber			
Fir	2.1	0.25	(1/4)
Maple	3.6	0.43	(7/16)
Oak	2.7	0.32	(5/16)
Pine	3.6	0.43	(7/16)
Wood, Perpendicular to Fiber			
Fir	32.0	3.84	(3-13/16)
Maple	27.0	3.24	(3-1/4)
Oak	30.0	3.6	(3-5/8)
Pine	19.0	2.28	(2-1/4)

Wood, masonry and concrete may expand with changes in moisture content. For concrete and wood products, these movements are reversible. For clay products masonry, in which the initial moisture expansion is not reversible at atmospheric temperatures and pressures, a moisture expansion design coefficient of 0.0002 is recommended for clay masonry. A shrinkage coefficient of 0.0005 is recommended for concrete.

Elastic deformation due to stress in the elastic range is approximately linear and is equal to the stress divided by the modulus of elasticity of the material.

When some materials are continuously stressed, there is a gradual yielding in the direction of the stress application. This is plastic flow, which is influenced not only by stress, but also by time and the physical properties of the material. A design value of 0.000001 per unit of length per psi is recommended for concrete. For example, a 100-ft long member, stressed to 1000 psi, would be expected to have a reduction in the length of 1.2 in.

In brick masonry, the units themselves are not subject to flow, although the mortar joints are. The joints, however, seldom comprise more than 15 or 20 per cent of the volume in compression. Limited research on creep for brick masonry suggests a design value of 0.0000002 per unit of length per psi.

Another major cause of movement in buildings is settlement and the action of unstable soil. Frequently, bearing wall buildings can be utilized to an advantage because the loads are delivered in lines rather than points, thus keeping the soil bearing stress low. Also, the walls can be designed as thin, deep beams which, when working with the footing, will be able to span weak spots or depressions in the subsoil.

The spacing of expansion joints in bearing walls need not be as close as for non-bearing walls because bearing walls are usually of greater strength and mass. Also, they are under higher stress, which in many cases will tend to restrain the walls, thus reducing movement. Where expansion joints are required, it is important to be careful to maintain the structural integrity of the wall.

Floor systems in bearing wall buildings will necessarily be influenced by structural requirements and by arrangements of bearing and shear walls. Joist systems and precast plank systems are satisfactory for most buildings, since they eliminate form work. Occasionally, two-way slabs, where the vertical load can be distributed in two directions, will offer a better floor system.

Control of Moisture and Temperature. In many buildings, cavity walls will meet the structural requirements, as well as provide walls which are resistant to water penetration, because of their internal drainage channels. Similar drainage channels can be built into walls which are furred on the inside, if through-the-wall flashing is used to collect any water which might penetrate the wall and divert it back to the outside through weep holes. These air spaces also provide convenient spaces for thermal insulation. Two types of pouring-type wall insulation have been investigated and found to be suitable for cavity walls. These are water-repellent vermiculite loose-fill insulation and water-repellent perlite loose-fill insulation. See *Technical Notes* 21 Series. Cavity walls can often be used as interior bearing walls to accommodate mechanical equipment which may run horizontally and vertically in the walls.

On exterior walls, care should be taken to avoid thermal bridges on which condensation may occur. In most climates, condensation will not occur on uninsulated masonry walls; however, through-the-wall metal elements may collect condensation on the inside. See *Technical Notes* 7C, "Moisture Control in Brick and Tile Walls - Condensation", and 7D, "Moisture Control in Brick and Tile Walls-Condensation Analysis".

In bearing wall buildings, some of the detailing problems are more critical, while others are minimized. There are few absolute answers to these problems. The best solution will stem from a rational analysis of the situation. Good details require ingenuity and imagination. There are no standard details which should be used without question. Each juncture of floor and wall should be considered as a separate problem and an appropriate detail developed for the situation.