BIA Technical Notes on Brick Construction

Brick Industry Association 11490 Commerce Park Drive, Reston, Virginia 20191

31B REVISED

Reissued* May 1987

STRUCTURAL STEEL LINTELS

Abstract: The design of structural steel lintels for use with brick masonry is too critical an element to be left to "rule-of-thumb" designs. Too little concern for loads, stresses and serviceability can lead to problems. Information is provided so that structural steel lintels for use in brick masonry walls may be satisfactorily designed.

Key Words: **beams** (supports); **brick**; **buildings**; **deflection**; **design**; lintels; **loads** (forces); **masonry**; structural steel; **walls**.

INTRODUCTION

A lintel is a structural member placed over an opening in a wall. In the case of a brick masonry wall, lintels may consist of reinforced brick masonry, brick masonry arches, precast concrete or structural steel shapes. Regardless of the material chosen for the lintel, its prime function is to support the loads above the opening, and it must be designed properly. To eliminate the possibility of structural cracks in the wall above these openings, the structural design of the lintels should not involve the use of "rule-of-thumb" methods, or the arbitrary selection of structural sections without careful analysis of the loads to be carried and calculation of the stresses developed. Many of the cracks which appear over openings in masonry walls are due to excessive deflection of the lintels resulting from improper or inadequate design.

This *Technical Notes* presents the considerations to be addressed if structural steel lintels are to be used. It also provides a procedure for the structural design of these lintels. For information concerning reinforced brick masonry lintels, see *Technical Notes* 17H and for brick masonry arches, see *Technical Notes* 31, 31A and 31C Revised.

CONSIDERATIONS

General

When structural steel lintels are used, there are several considerations which must be addressed in order to have a successful design. These include loading, type of lintel, structural design, material selection and maintenance, moisture control around the opening, provisions to avoid movement problems and installation of the lintel in the wall.

Types

There are several different types of structural steel lintels used in masonry. They vary from single angle lintels in cavity or veneer walls, to steel beams with plates in solid walls, to shelf angles in brick veneer panel walls. Most building codes permit steel angle lintels to be used for openings up to 8 ft 0 in. (2.4 m). Openings larger than this are usually required to have fire protected lintels.

Loose Angle Lintels. Loose angle lintels are used in brick veneer and cavity wall constructions where the lintel is laid in the wall and spans the opening. This type of lintel has no lateral support. Figure 1a shows this condition.

Combination Lintels. In solid masonry walls, single loose angle lintels are usually not capable of doing the job. Therefore, combination lintels are required. These combination lintels can take many forms, from a clustering of steel angles, such as shown in Figs. 1b and 1c, to a combination of steel beam and plates, as shown in Figs. 1d and 1e.

Angle Lintels - In solid masonry walls, it is usually satisfactory to use multiple steel angles as a lintel. These angles are usually placed back to back, as shown in Figs. 1b and 1c.

Steel Beam/Plate Lintels - In solid walls with large superimposed loads, or in walls where the openings are greater than 8 ft 0 in. (2.4 m), it may be necessary to use lintels composed of steel beams with attached or suspended plates, as shown in Figs. 1d and 1e. This permits the beam to be fully encased in masonry, and fire-protected.

Shelf Angles. In panel walls systems, the exterior wythe of brickwork may be supported by shelf angles rigidly attached to the structural frame. These shelf angles, in some cases, also act as lintels over openings in the masonry. This condition is shown in Fig.1f.

*Originally published in Nov/Dec 1981, this *Technical Notes* has been reviewed and reissued.

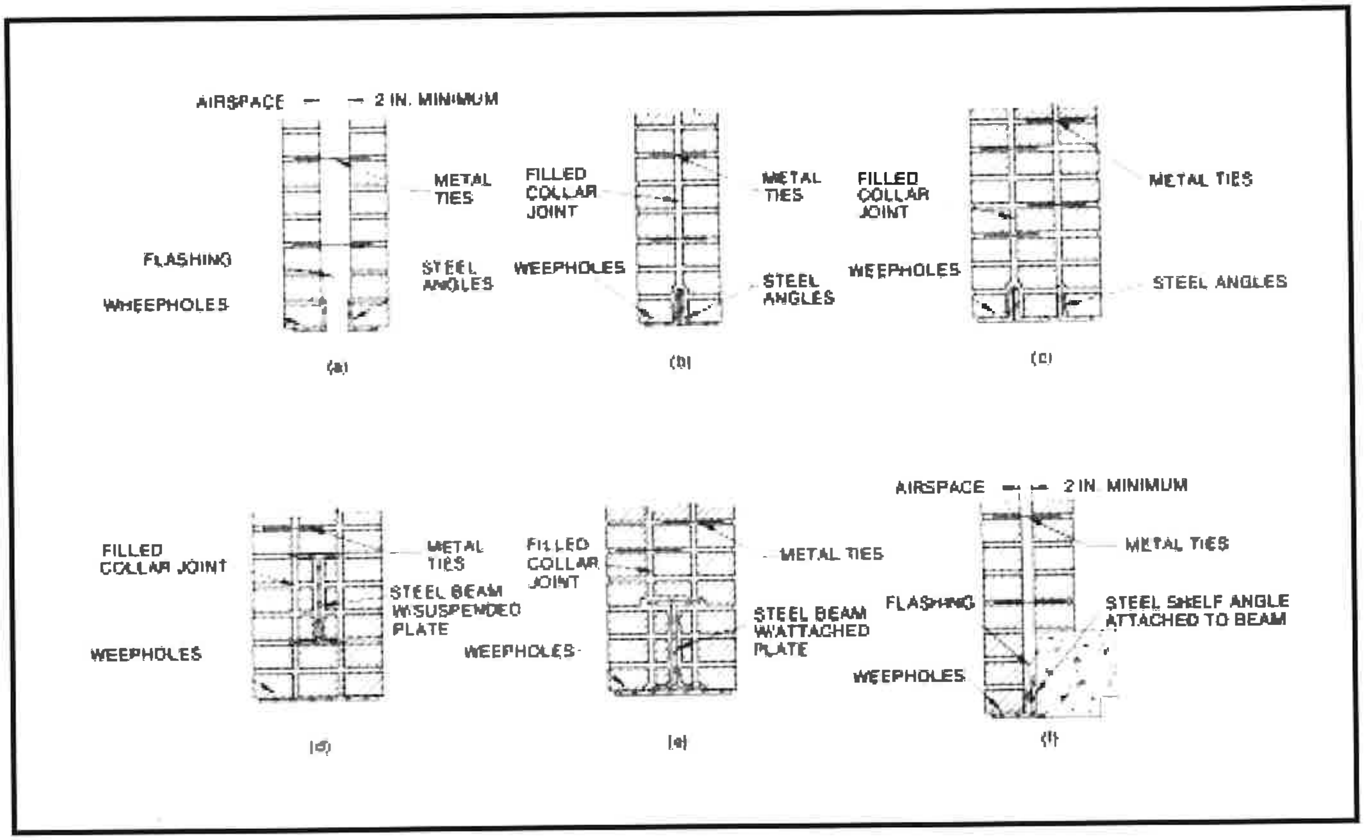

Fig. 1
Types of Structural Steel Lintels

Design

The proper design of the structural steel lintel is very important, regardless of the type used. The design must meet the structural requirements and the serviceability requirements in order to perform successfully. Design loads, stresses and deflections will be covered in a later section of this *Technical Notes*.

Materials

The proper specification of materials for steel lintels is important for both structural and serviceability requirements. If materials are not properly selected and maintained, problems can occur.

Selection. The steel for lintels, as a minimum, should comply with ASTM A 36. Steel angle lintels should be at least 1/4 in. (6 mm) thick with a horizontal leg of at least 3 1/2 in. (90 mm) for use with nominal 4 in. (100 mm) thick brick, and 3 in. (75 mm) for use with nominal 3 in. (75 mm) thick brick.

Maintenance. For harsh climates and exposures, consideration should be given to the use of galvanized steel lintels. If this is not done, then the steel lintels will require periodic maintenance to avoid corrosion.

Moisture Control

Proper consideration must always be given to moisture control wherever there are openings in masonry walls. There must always be a mechanism to channel the flow of water, present in the wall, to the outside.

Flashing and Weepholes. Even where galvanized or stainless steel angles are used for lintels in cavity and veneer walls, continuous flashing should be installed over the angle. It should be placed between the steel and the exterior masonry facing material to collect and divert moisture to the outside through weepholes. Regardless of whether flashing is used, weepholes should be provided in the facing at the level of the lintel to permit the escape of any accumulated moisture. See *Technical Notes* 7A for further information on flashing and weepholes.

Movement Provisions

Because of the diversity of movement characteristics of different materials, it is necessary to provide for differential movement of the materials. This is especially true at locations where a number of different materials come together. *Technical Notes* 18 Series provides additional information on differential movement.

Expansion Joints. Expansion joints in brick masonry are very important in preventing unnecessary and unwanted cracking. There are two types of expansion joints which will need to be carefully detailed when lintels are involved: vertical and horizontal.

Vertical - Vertical expansion joints are provided to permit the horizontal movement of the brick masonry. Where these expansion joints are interrupted by lintels, the expansion joint should go around the end of the lintel and then continue down the wall.

Horizontal - In multi-story walls where the lintels are a continuation of shelf angles supporting masonry panels, horizontal expansion joints to accommodate vertical movement must be provided. Often a simple soft joint below the shelf angle is all that is needed. See *Technical Notes* 18A, 21 Rev, and 28B Rev for typical details.

Installation

The installation of steel lintels in masonry walls is a conventional construction operation, familiar to most members of the building team. The walls are built to the height of the opening, the lintel is placed over the opening, and the masonry work is continued. One item of special construction that must be noted is temporary shoring.

Temporary Shoring. If the steel lintel is being designed assuming in-plane arching of the masonry above, then the lintel must be shored until the masonry has attained sufficient strength to carry its own weight. This shoring period should not be less than 24 hr. This minimum time period should be increased to three days when there are imposed loads to be supported. If the masonry is being built in cold weather construction conditions, the length of cure should be increased. If the lintel is designed for the full uniform load of the masonry and other superimposed loads ignoring any inherent arching action, then no shoring is required.

STRUCTURAL DESIGN

General

The structural design of steel lintels is relatively simple. The computations are the same as for steel beams in a building frame, but because of the low elasticity of the masonry, and the magnitude and eccentricity of the loading, the design should not be taken lightly. A proper design must consider the loads, stresses, and serviceability of the system. If these are not properly taken into account, problems of cracking and spalling could occur.

Loads

The determination of imposed loads is an important factor. Fig. 2 shows an example of a lintel design situation. On the left is an elevation showing an opening in a wall with planks and a beam bearing on the wall. On the right is a graphic illustration of the distribution of the superimposed loads.

Uniform Loads. The triangular wall area (ABC) in Fig. 2b above the opening has sides at 45-deg angles to the base. Arching action of a masonry wall will carry the dead weight of the wall and the superimposed loads outside this triangle, provided that the wall above Point B (the top of the triangle) is sufficient to provide resistance to arching thrusts. For most lintels of ordinary wall thickness, loads and spans, a depth of 8 to 16 in. (200 mm to 400 mm) above the apex is sufficient. If stack bonded masonry is used, horizontal joint reinforcement must be provided to ensure the arching action.

Providing arching action occurs, the dead weight of the masonry wall, carried by the lintel, may be safely assumed as the weight of masonry enclosed within the triangular area (ABC). To the dead load of the wall must be added the uniform live and dead loads of the floor bearing on the wall above the opening and below the apex of the 45-deg triangle. Again, providing arching occurs, such loads above the apex may be neglected. In Fig. 2b, D is greater than L/2, so the floor load may be ignored, but, in order to use this assumed loading, temporary shoring must be provided until the masonry has cured sufficiently to assure the arching action.

If arching action is not assumed and temporary shorting is not to be used, the steel lintel must be designed for the full weight of the masonry and other superimposed live and dead loads above the opening. There could be quite a substantial difference in the final lintel sizes required in each case.

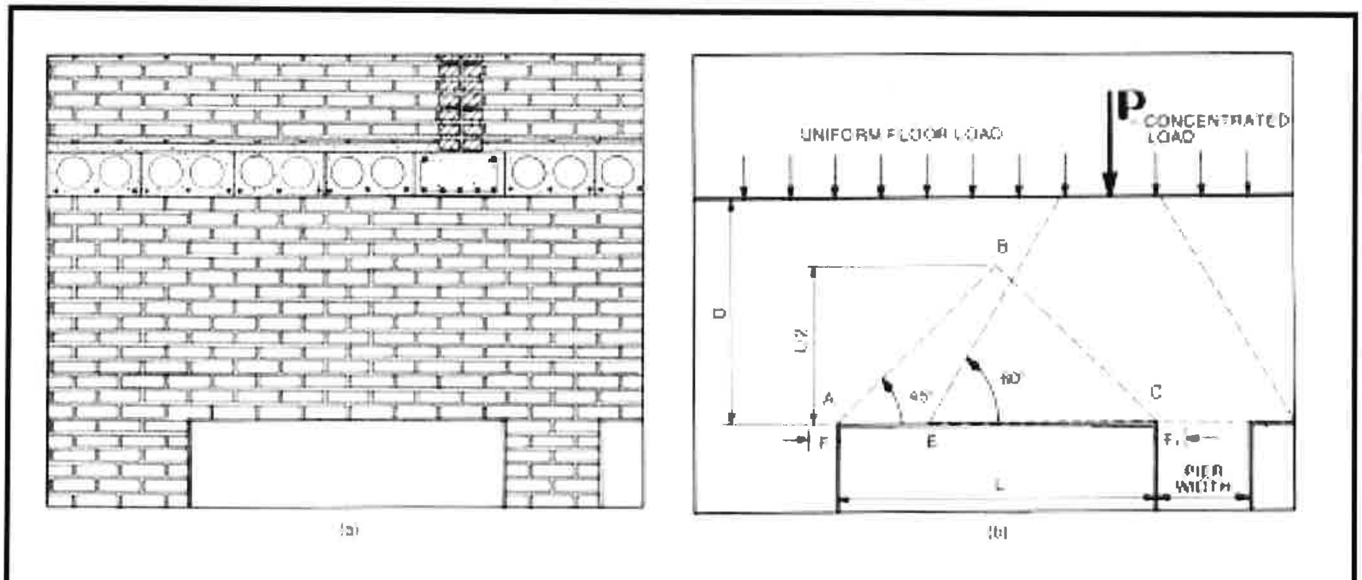

Fig. 2
Lintel Load Determination

Concentrated Loads. Concentrated loads from beams, girders, or trusses, framing into the wall above the opening, must also be taken into consideration. Such loads may be distributed over a wall length equal to the base of the trapezoid and whose summit is at the point of load application and whose sides make an angle of 60 deg with the horizontal. In Fig. 2b, the portion of the concentrated load carried by the lintel would be distributed over the length, EC, and would be considered as a partially distributed uniform load. Arching action of the masonry is not assumed when designing for concentrated loads. Again, if stack bonded masonry is used, horizontal joint reinforcement must be provided to assure this distribution.

Stresses

After the loads have been determined, the next step in the design of the lintel is the design for stresses. Which stresses need to be checked will depend upon the type and detailing of the lintel.

Flexure. In a simply supported member loaded through its shear center, the maximum bending moment due to the triangular wall area (ABC) above the opening can be determined by:

$$M_{max} = \frac{WL}{6}$$

where:

M_{max} = maximum moment (ft---lb)

W = total load on lintel (lb)

L = span of lintel, center to center of end bearing (ft)

As an alternative, the designer may wish to calculate an equivalent uniform load by taking 2/3 of the maximum height of the triangle times the unit weight of the masonry as the uniform load across the entire lintel. If this is done, the maximum bending moment equation becomes:

$$M_{max} = \frac{wL^2}{8}$$

where:

w = equivalent uniformly distributed load per unit of length (lb per ft).

To this bending moment should be added the bending moment caused by the concentrated loading, if any. Where such loads are located far enough above the lintel to be distributed as shown in Fig. 2b, the bending moment formula for a partially distributed uniform load may be used. Such formulae may be found in the " Manual of Steel Construction," by the American Institute of Steel Construction (AISC). Otherwise, concentrated load bending moments should be used.

The next step is the selection of the required section. The angle, or other structural steel shape, should be selected by first determining the required section modulus. This becomes:

$$S = \frac{12M_{max}}{F_b}$$

where:

S = section modulus (in^3)

F_b = allowable stress in bending of steel (psi)

The allowable stress, F_b, for ASTM A 36 structural steel is 22,000 psi (150 MPa) for members laterally supported. Solid brick masonry walls under most conditions provide sufficient lateral stiffness to permit the use of the full 22,000 psi (150 MPa). This is especially true when floors or roofs frame into the wall immediately above the lintel. The design for non-laterally supported lintels should be in accordance with the AISC *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.*

Using the design property tables in the AISC Manual, a section having an elastic section modulus equal to, or slightly greater than, the required section modulus is selected. Whenever possible, within the limitations of minimum thickness of steel and the length of outstanding leg required the lightest section having the required section modulus should be chosen.

Combined Flexure and Torsion. In some cases, the design for flexure will need to be modified to include the effects of torsion. This is the case in cavity and veneer walls where the load on the angle is not through the shear center.

In some situations, such as veneers, panel or curtain walls, the lintel may be supporting only the triangular portion of masonry directly over the opening. If this is the case, then the torsional stresses will usually be negligible compared to the flexural stresses, and can be safely ignored.

If, on the other hand, there are imposed uniform loads within the triangle or imposed concentrated loads above the lintel, then a detailed, combined stress analysis will be necessary. The design of a lintel subjected to combined flexure and torsion should be in accordance with the AISC *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.*

Shear. Shear is a maximum at the end supports, and for steel lintels it is seldom critical. However, the computation of the unit shear is a simple calculation and should not be neglected. The allowable unit shear value for ASTM A 36 structural steel is 14,500 psi (100 MPa). To calculate the shear:

$$V_{max} = \frac{R_{max}}{A_s}$$

where:

V_{max} = the actual maximum unit shear (psi)

R_{max} = maximum reaction (lb)

A_s = area of steel section resisting shear (sq. in.)

Bearing. In order to determine the overall length of a steel lintel, the required bearing area must be determined. The stress in the masonry supporting each end of the lintel should not exceed the allowable unit stress for the type of masonry used. For allowable bearing stresses, see "Building Code Requirements for Engineered Brick Masonry," BIA; "American Standard Building Code Requirements for Masonry," ANSI A41.1-1953 (R 1970); or the local building code. The reaction at each end of the lintel will be one-half the total uniform load on the lintel, plus a proportion of any concentrated load or partially distributed uniform load. The required area may be found by:

$$A_b = \frac{R_{max}}{f_m}$$

where:

A_b = required bearing area (sq in.)

f_m = allowable compressive stress in masonry (psi)

In addition, any stresses due to rotation from bending or torsion of the angle at its bearing must be taken into account.

Since in selecting the steel section, the width of the section was determined, that width divided into the required bearing area, A_b, will determine the length of bearing required, F and F_1, in Fig. 2b. This length should not be less than 3 in. (75 mm).

If the openings are close together, the piers between these openings must be investigated to determine whether the reactions from the lintels plus the dead and live loads acting on the pier exceed the allowable unit compressive stress of the masonry. This condition will not normally occur where the loads are light, such as in most one and two-story structures.

Serviceability

In addition to the stress analysis for the lintel, a serviceability analysis is also important. Different types of lintels have different problems of deflection and rotation, and each must be analyzed separately to assure its proper performance.

Deflection Limitations. After the lintel has been designed for stresses, it should be checked for deflection. Lintels supporting masonry should be designed so that their deflection does not exceed 1/600 of the clear span nor more than 0.3 in (8 mm) under the combined superimposed live and dead loads.

For uniform loading, the deflection can be found by:

$$\Delta_t = \frac{5wl^4(1728)}{384\,EI}$$

where:

Δ_t = total maximum deflection (in.)

E = modulus of elasticity of steel (psi)

I = moment of inertia of section ($in.^4$)

For loadings other than uniform, such as concentrated loads and partially distributed loads, deflection formulae may be found in the AISC Manual.

Torsional Limitations. In cases where torsion is present, the rotation of the lintel can be as important as its deflection. The rotation of the lintel should be limited to 1/16 in. (1.5 mm) maximum under the combined superimposed live and dead loads. As mentioned before, all additional bearing stresses due to angle rotation must be taken into account in the design for bearing.

Design Aids

In order to facilitate the design of steel angle lintels, several design aids are included. These design aids are not all-inclusive, but should give the designer some help in designing lintels for typical applications. Conditions beyond the scope of these tables should be thoroughly investigated.

Table 1 contains tabulated load values to assist the designer in the selection of the proper size angle lintel, governed either by moment or deflection under uniform load. Shear does not govern in any of the listed cases. The deflection limitation in Table 1 is 1/600 of the span, or 0.3 in. (8 mm), whichever is less. Lateral support is assumed in all cases.

Table 2 lists the allowable bearing stresses taken from ANSI A41.1-1953 (R 1970). In all cases, allowable bearing stresses set by local jurisdictions in their building codes will govern.

Table 3 lists end reactions and required length in bearing, which may control for steel angle lintels.

SUMMARY

This *Technical Notes* is concerned primarily with the design of structural steel lintels for use in brick masonry walls. It presents the considerations which must be addressed for the proper application of this type of masonry support system. Other *Technical Notes* address the subjects of reinforced brick masonry lintels and brick masonry arches.

The information and suggestions contained in this *Technical Notes* are based on the available data and the experience of the technical staff of the Brick Institute of America. The information and recommendations contained herein, if followed with the use of good technical judgment, will avoid many of the problems discussed. Final decisions on the use of details and materials as discussed are not within the purview of the Brick Institute of America, and must rest with the project designer, owner, or both.

TABLE 1

Allowable Uniform Superimposed Load (lb per ft) for ASTM A 36 Structural Steel Angle Lintels [1,2,3,4,5,6]

Horizontal Leg (in)	Angle Size (in x in x in)	Weight per ft (lb)	Span in Feet (Center to Center of Required Bearing						Resisting Moment (ft-lb)	Elastic Section Modulus (in^3)	Moment of Inertia (in^4)
			3	4	5	6	7	8			
2 1/2	2 x 2 1/2 x 1/4	3.6	352	146	73				458	0.25	0.372
	2 1/2 x 2 1/2 x 1/4	4.1	631	279	141	80			715	0.39	0.703
	5/16	5.0	777	336	170	96			880	0.48	0.849
	3/8	5.9	923	390	197	112			1045	0.57	0.984
	3 x 2 1/2 x 1/4	4.5	908	467	237	135	83		1027	0.56	1.17
	3 1/2 x 2 1/2 x 1/4	4.9	1233	692	366	210	130	86	1393	0.76	1.80
	5/16	6.1	1509	846	446	255	158	104	1705	0.93	2.19
	3/8	7.2	1769	992	521	298	185	122	1998	1.09	2.56
3 1/2	2 1/2 x 3 1/2 x 1/4	4.9	664	308	155	88			752	0.41	0.777
	3 x 3 1/2 x 1/4	5.4	956	518	263	150	92		1082	0.59	1.30
	3 1/2 x 3 1/2 x 1/4	5.8	1281	718	409	234	145	95	1448	0.79	2.01
	5/16	7.2	1590	891	498	285	177	116	1797	0.98	2.45
	3/8	8.5	1865	1046	583	334	207	136	2108	1.15	2.87
	4 x 3 1/2 x 1/4	6.2	1672	938	594	341	212	140	1888	1.03	2.91
	5/16	7.7	2046	1147	726	417	260	172	2310	1.26	3.56
	5 x 3 1/2 x 5/16	8.7	3153	1770	1130	779	487	324	3557	1.94	6.60
	3/8	10.4	3721	2089	1333	918	574	381	4198	2.29	7.78
	6 x 3 1/2 x 3/8	11.7	5268	2958	1889	1308	958	638	5940	3.24	12.90

[1] Allowable loads to the left of the heavy line are governed by moment, and to the right by deflection.

[2] F_b = 22,000 psi (150 MPa)

[3] Maximum deflection limited to L/600

[4] Lateral support is assumed in all cases.

[5] For angles laterally unsupported, allowable load must be reduced.

[6] For angles subjected to torsion, make special investigation.

TABLE 2

Allowable Compressive Stresses (psi) in Masonry [1]

Type of Wall	Type of Mortar			
	M	S	N	O
Solid walls of brick or solid units of clay when average compressive strength of unit is as follows:				
8000 plus psi	400	350	300	200
4500 to 8000 psi	250	225	200	150
2500 to 4500 psi	175	160	140	110
1500 to 2500 psi	125	115	100	75
Grouted solid masonry of brick and other solid units of clay				
4500 plus psi	350	275	200	-
2500 to 4500 psi	275	215	155	-
1500 to 2500 psi	225	175	125	-
Masonry of hollow units	85	75	70	-

1 Adapted from "American Standard Building Code Requirements for Masonry," National Bureau of Standards, ANSI A41. 1-1953 (R 1970).

TABLE 3

End Reaction[1] and Required Length of Bearing[2] for Structural Angle Lintels

2 1/2" Leg Horizontal				
f_m psi	Length of Bearing			
	3	4	5	6
400	3000	4000	5000	6000
350	2625	3500	4375	5250
300	2250	3000	3750	4500
275	2063	2750	3438	4125
250	1875	2500	3125	3750
225	1688	2250	2813	3375
215	1613	2150	2688	3225
200	1500	2000	2500	3000
175	1313	1750	2188	2625
160	1200	1600	2000	2400
155	1163	1550	1938	2325
150	1125	1500	1875	2250
140	1050	1400	1750	2100
125	938	1250	1563	1875
115	863	1150	1438	1725
110	825	1100	1375	1650
100	750	1000	1250	1500
85	638	850	1063	1275
75	563	750	938	1125
70	525	700	875	1050

31/2" Leg Horizontal				
f_m psi	Length of Bearing			
	3	4	5	6
400	4200	5600	7000	8400
350	3675	4900	6125	7350
300	3150	4200	5250	6300
275	2888	3850	4813	5775
250	2625	3500	4375	5250
225	2363	3150	3938	4725
215	2258	3010	3763	4515
200	2100	2800	3500	4200
175	1838	2450	3063	3675
160	1680	2240	2800	3360
155	1628	2170	2713	3255
150	1575	2100	2625	3150
140	1470	1960	2450	2940
125	1313	1750	2188	2625
115	1208	1610	2013	2415
110	1155	1540	1925	2310
100	1050	1400	1750	2100
85	893	1190	1488	1785
75	788	1050	1313	1575
70	735	980	1225	1470

[1] End Reaction in lbs.
[2] Length of Bearing in inches.

REFERENCES

1. AISC, *Manual of Steel Construction*, American Institute of Steel Construction, Inc., New York, New York, Eighth Edition, 1980.
2. AISC, *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings*, American Institute of Steel Construction, Inc., New York, New York, 1978.
3. ANSI, *American Standard Building Code Requirements for Masonry*, ANSI A41.1-1953 (R 1970), American National Standards Institute, New York, New York.
4. BIA, *Building Code Requirements for Engineered Brick Masonry*, Brick Institute of America, McLean, Virginia, 1969.