V-5. Brick Clad Loadbearing Masonry Structures—The Ottawa Experience

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ABSTRACT

During the past decade an increasing number of brick veneer cracking problems have been made public, largely through the media and publications in Canada, the USA and Britain. Based on this poor veneer performance and its resultant adverse publicity, the logical question arises as to whether brick masonry is at all appropriate as veneer and in what types of structures it might possibly perform well at reasonable economic cost. A closer look at the cracking evidence shows that one must distinguish between the various structural systems associated with brick veneer; these systems could be loadbearing shear wall structures of masonry or concrete as well as framed structures of concrete or steel. The paper deals with the case of brick veneer used in conjunction with loadbearing masonry and is based on the satisfactory cavity wall construction experience in the Ottawa area over the past 10 years. The Ottawa experience encompasses over 40 loadbearing masonry structures varying from 4 to 14 storeys in height. The veneer's performance is discussed in relation to a number of key parameters. These parameters are dealt with in the paper under the headings of design and construction, accommodation of deformations, and moisture penetration. The paper's findings show that brick masonry veneer works well when used in conjunction with loadbearing masonry, provided due consideration is given to the behaviour of the masonry veneer materials as well as to the veneer's compatibility with the loadbearing system. The paper concludes with a look at the implications of increasing energy conservation requirements on cavity wall construction in general and on possible brick veneer problems in particular.

INTRODUCTION

During the past decade an increasing number of brick veneer cracking problems have been made public, largely through the media and publications in Canada, the USA and Britain. Based on this poor veneer performance and its resultant adverse publicity, the logical question arises as to whether brick masonry is at all appropriate as veneer and in what types of structures it might possibly perform well at reasonable economic cost. A closer look at the cracking evidence shows that one must distinguish between the various structural systems associated with brick veneer; these systems could be loadbearing shear wall structures of masonry or concrete as well as framed structures of concrete or steel. The paper deals with the case of brick veneer used in conjunction with loadbearing masonry and is based on the satisfactory cavity wall construction experience in the Ottawa area over the past 10 years. The Ottawa experience encompasses at least 30 loadbearing masonry structures of varying shapes and heights as outlined in Table 1. The tabular evidence indicates that the majority of structures are greater or equal to 10 storeys in height, hence the paper concentrates on the brick veneer performance of medium-rise to highrise buildings.

What is the basic function of a veneer in connection with a loadbearing masonry structure? It essentially represents an outer skin which must be durable, be resistant to water penetration, possess reasonable thermal insulating properties and be attractive. Veneer used in cavity walls can fulfill all these requirements economically as long as the two key factors affecting the performance of a veneer are properly dealt with; these two key factors are the design and the construction of the wall. For the cavity walls typically utilized in the Ottawa area—a loadbearing inner wythe of 6 in. or 8 in. concrete block and a non-loadbearing outer clay brick veneer most frequently 4 in. thick—the paper focusses firstly on aspects of overall design as well as detailed design, and secondly on construction requirements. The paper concludes with a look at the implications of increasing energy conservation requirements on cavity wall construction in general and on possible brick veneer problems in particular.

DESIGN

Overall Design

The Ottawa requirements pertaining to veneer design given in Table 2 indicate that cavity walls must be capable of resisting substantial lateral loads while accommodating large thermal movements and resisting significant water penetration. In other words, the loading and serviceability requirements are relatively severe. The wall sections of Figs. 1 and 2 show some typical details for the Ottawa

structures. Starting with strip footings—an economical solution for local clay soil conditions[3]—the 12 in. thick foundation walls serve as a stiff base for the brick veneer. The continuous joint reinforcement, typically of truss type and spaced at 16 in. centers vertically, provides lateral support for the slender skin of veneer and at the same time transfers lateral loads from the veneer to the structural backup. Note that the amount of reinforcement used in the Ottawa structures complies with the minimum building code requirements[2] but does not exceed them unless loading conditions so dictate. The 1.5 in. width of cavity shown in Figs. 1 and 2 is found to be adequate to achieve three key effects: Firstly, to separate the skin and backup without initiating distress; secondly, to drain any water penetrating the veneer downwards to the flashing and weepholes; and thirdly, to provide a relatively short and therefore stiff length for the crossrods of the continuous joint reinforcement.

Experience has shown the narrow cavity of 1.5 in. may be bridged at times by mortar droppings or mortar fins and this may lead to a small degree of water penetration towards the inside of the structure. However, such occurrences have been very infrequent and even then only localized. Note that the insulation typically is placed on the inside face of the loadbearing wythe and not in the cavity. While this leads to some theoretical inefficiency as far as the thermal design of the building is concerned, construction experience in Ottawa has shown this to be economically and practically the best overall solution.

Further to the basic aspects of cavity wall design and their effect on veneer behavior, what is of particular interest is the consideration of wall openings. Of concern here are the size, shape and location of openings as well as how the architectural requirement of openings leads to a natural structural division of wall elements of limiting width. For the Ottawa situation, Fig.3 depicts commonly used arrangements. Fig.3a, showing part of a typical building's elevation, indicates that the location of balconies and windows limits the wall width usually to less than 3 ft. Such a natural division of the building's walls into short vertical elements is of course desirable to prevent vertical or inclined cracking of the veneer due to restrained movements in the longitudinal direction of a structure. Figs. 3b and 3c deal with two specific cases of window openings in walls. Fig. 3b shows the case where the openings are essentially punched through the entire thickness of cavity wall and the wall acts as one wider element. The ratio of overall height to overall width, H/T, will then be relatively small, say in the order of 4. The other popular configuration calls for thermally insulated panels which span vertically between window openings as indicated in Fig. 3c. The panels replace the brick veneer in these locations and hence the H/T ratio of the veneer wall sections increases to between 20 and 30. Since wall openings tend to act as stress raisers and hence could lead to possible veneer cracking, the configuration of Fig.3c represents a less severe situation since the vertical veneer wall elements are relatively flexible and continuous. Nevertheless, with the typical reinforcement provided around openings as shown in Fig.4, the Ottawa structures have shown virtually no veneer cracking for either case of Fig.3b or 3c. Note that present Canadian code requirements stipulate only the horizontal reinforcement[2], however wall sections are typically reinforced as shown in Fig. 4 according to earlier code requirements[4].

Finally in this section on overall design, a comment should be made about the type of floor employed in the Ottawa structures and particularly about the floor—wall detail depicted in Fig.2. The most commonly used floor system for loadbearing masonry structures in the Ottawa area consists of a composite open web steel joist—reinforced concrete slab system[3]. The 2.5 in. concrete slab is relatively flexible and together with the joist shoe reaction introduces only small eccentricities or rotations into the loadbearing masonry wythe. The floor-wall detail therefore does not lead to possible cracking in the concrete masonry which in turn could lead to cracking in the veneer. Indeed no veneer distress cases are known to the authors for the floor-wall regions of the Ottawa structures. Note that in no case would the authors recommend a floor slab to bridge across the cavity unto the veneer.

Design of Details

In a recent interview dealing with veneer probelms J. Stockbridge of Wiss, Janney, Elstner & Associates was quoted as saying: "Quite often . . . . a building's skin is not engineered to the same extent as the rest of the building"[5]. What might be appropriate to add here is the fact that the design of details often does not receive the attention it requires and yet it is precisely this detailed design which is vitally important to the veneer's satisfactory performance. In cavity wall construction where the building's skin or veneer is not loadbearing, the designer must clearly visualize and then detail the transmission of loads to the loadbearing masonry wythe without affecting the veneer. In any structure a large number of details are required to achieve the proper actions for both the veneer and the loadbearing wythe. The three cases shown in Figs. 5, 6 and 7 illustrate three important examples from the authors' practice.

Figs. 5 and 6 refer to balcony details where the precast or cast-in-place balcony is an extension of the floor slab. In Fig.5 the balcony support reactions are transferred into the grouted loadbearing wall element designated as 'A' on the diagram. A cut-out in the slab is used to provide a free joint around the brick veneer while giving at the same time the visual impression of a continuous veneer.

Fig.6 illustrates the case where the architectural design of the facade calls for brick piers which extend the full height of the building on either side of the balconies. While the brick piers are readily utilized as loadbearing elements for the balcony reactions, what is of great importance here is to detail a clear separation between the loadbearing piers and the non-loadbearing veneer. The continuous vertical joint indicated in Fig.6 achieves this effect.

Frequently large steel beams of entrance canopies or a building's foyer interrupt the veneer to be supported either by hidden steel columns or masonry piers. Here again, the brick veneer must be separated from the steel beam. Further, if the veneer opening is relatively wide as in the case of wide-flange beams, steel lintels as shown in

Fig.7 are built into the veneer and used to support the brick masonry above the opening.

CONSTRUCTION

Careful overall and detailed design of cavity walls, and in particular the veneer, must be accompanied by proper construction to achieve satisfactory veneer performance. This means for instance that blockages of the cavity due to mortar droppings and fins must be minimized and the continuous joint reinforcement must be installed as specified. Where blockages occur, it is the authors' opinion that they will be localized with few, if any, adverse effects. This is so because in cavity wall construction no continuous veneer supports such as shelf angles or brick headers exist around the structure's perimeter, hence there exists always some open route within the cavity for moisture to drain down to the flashing and out through the weepholes.

To control the construction of loadbearing masonry structures of the type dealt with in this paper, the authors utilize and recommend full-time inspection. The authors strongly feel that only full-time inspection can monitor and control the continuous construction process of loadbearing masonry structures, a situation that contrasts with reinforced concrete and steel construction where different construction activities recur in cycles.

A number of veneer construction problems have arisen at times; these include

- use of cracked bricks
- incompletely filled joints
- poor tooling of joints
- use of sand containing organic material, and
- poor installation of caulking

It is the job of both the masonry contractor and the resident inspector to help minimize these problems and to ensure above all that the veneer details are constructed as specified. Only in this way can the veneer perform satisfactorily with safety and a minimum of maintenance during the life of the structure.

EFFECT OF ENERGY CONSERVATION

Increased requirements for energy conservation recently have led to additional insulation provisions in our walls and will undoubtedly have an impact on the future of masonry construction. The authors will restrict their discussion here to the effect of greater energy conservation on cavity walls.

Increased energy conservation can be achieved by an increase in the thickness of insulation and by placing the insulation in a more efficient position than that shown in Fig.2 for the Ottawa structures. On the assumption that the basic masonry material of brick and block remain the same as at present—a realistic view certainly for the immediate future—the extra thickness of insulation may be placed inside a wider cavity against the loadbearing masonry wythe. Does this lead to a feasible solution and if not, why not? For the cavity still to function as a cavity, i.e., primarily to retain its moisture draining ability and permit relatively unrestrained movement between the building's skin and the structure, an air space of at least 1 in. width must be maintained. Since the thickness of insulation according to current thinking may vary between 2 and 5 in., a width of cavity between 3 and 6 in. is required. Structurally this will require thicker crossrods or a closer spacing of joint reinforcement in order to transmit lateral veneer loads to the structural backup. However, thicker crossrods may be difficult to accommodate in a standard mortar joint and a closer spacing of reinforcement, say at 8 in. centers vertically, would make the placement of insulation and proper sealing of joints exceedingly difficult.

Another more basic problem about the construction process surfaces now. Presently all loadbearing masonry structures in the Ottawa area are constructed by the overhead laying method, i.e. from inside the structure without the use of exterior scaffolding. This efficient process would no longer be very practical if insulation were placed inside the cavity.

In summary, the authors feel that the placement of insulation inside the cavity does not lead to a feasible and economic solution. The alternative is to locate it on the inside of the loadbearing wall, and possibly to pay a premium for dense insulation of high thermal resistance to achieve relatively thinner wall sections. It is the authors' opinion that in remaining with the proven system of cavity wall construction not only are its well-known economics utilized but the system's good performance remains unaltered. While this recommendation for the status quo is not an exciting new one that opens opportunities for utilizing masonry in novel ways, it represents a feasible solution which gives some confidence for the continued satisfactory performance of the veneer.

CONCLUSIONS

For the Ottawa experience consisting of 30 loadbearing masonry structures built over the past 10 years, brick veneer in conjunction with cavity wall construction has demonstrated satisfactory performance in every structure. Based on the Ottawa buildings, the paper discusses aspects of design and construction which are key factors in achieving satisfactory veneer performance.

The authors stress the necessity firstly, of careful attention being given to the design and construction of details and secondly, of full-time inspection being employed during the continuous construction process of loadbearing masonry structures.

To meet increased wall insulation requirements, and achieve satisfactory veneer performance at the same time, the authors recommend the continued use of the proven cavity wall construction concept employing a narrow cavity with the additional insulation to be placed on the inside of the loadbearing masonry wythe.

It is hoped that the paper's discussion of the satisfactory Ottawa veneer experience will contribute to the body of knowledge which designers can utilize to achieve safe and serviceable brick veneers in the future.

REFERENCES

1. National Building Code of Canada 1977.
2. Canadian Standards Association CSA S304-1977.
3. Suter, G.T., H. Keller, J.S. Hall and A.J. .Garwood, "Case Study of a Typical Loadbearing Masonry Apartment Building in Ottawa, Canada", Proceedings of the British Ceramic Society, London, December 1977.
4. National Building Code of Canada, Supplement No. 4, 1975.
5. Engineering News Record, April 19, 1979, p. 12.

ACKNOWLEDGEMENTS

The authors acknowledge with thanks the financial support provided by the National Research Council of Canada and the Canadian Masonry Research Council.

Table 1—Summary of Types of Ottawa Loadbearing Masonry Structures

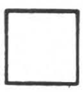
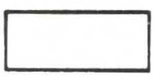
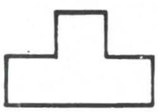
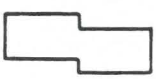
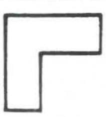
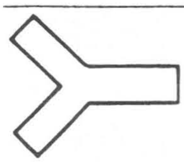
SHAPE IN PLAN VIEW	NO. OF STOREYS	NO. OF BUILDINGS
	8 10 12 14	1 2 1 1
	7 10 11	3 5 1
	6	1
	8 9 10 12	1 1 1 5
	12	2
	11 12 13	1 3 1
Total	23/30 ≥ 10 15/30 > 10	30

Table 2—Summary of Ottawa Requirements

DESIGN REQUIREMENTS	
TYPE	MAGNITUDE
Earthquake (1)	Medium intensity (horizontal ground acceleration equal to 4% of gravity)
Wind (1)	Medium intensity (7.8 psf for 30 year return period)
Temperature	Ave. High (July): 26°C Ave. Low (January): -16°C
Precipitation per year	Rain: 640 mm Snow: 250 cm
Minimum Reinforcement (2) (Loadbearing walls only)	Vertical*: $A_v = 0.002\ A_g\ \alpha$ Horizontal*: $A_h = 0.002\ A_g(\alpha-1)$

*α = reinforcement distribution factor varying from 0.33 - 0.67 as determined by the designer.

A_v = area of vertical steel per foot of wall, in^2.

A_h = area of horizontal steel per foot of wall, in^2.

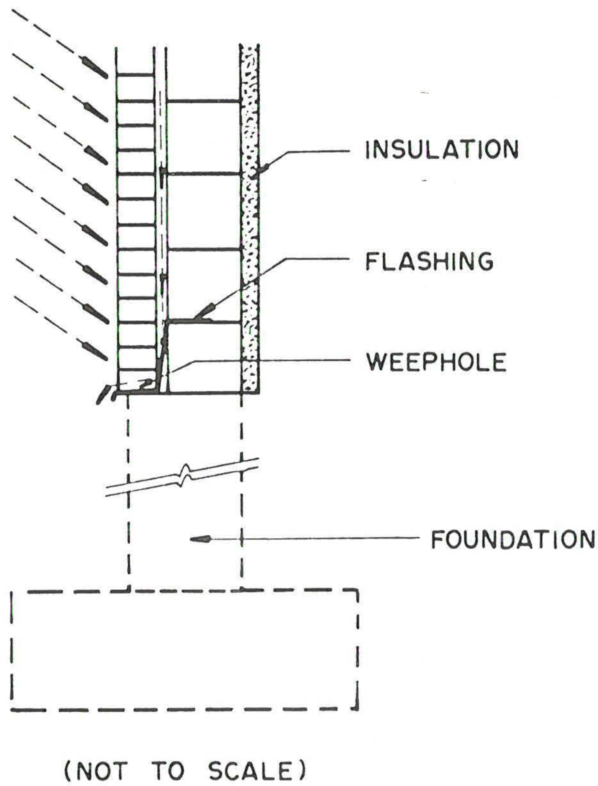


Figure 1 Veneer Acting As Rain Screen

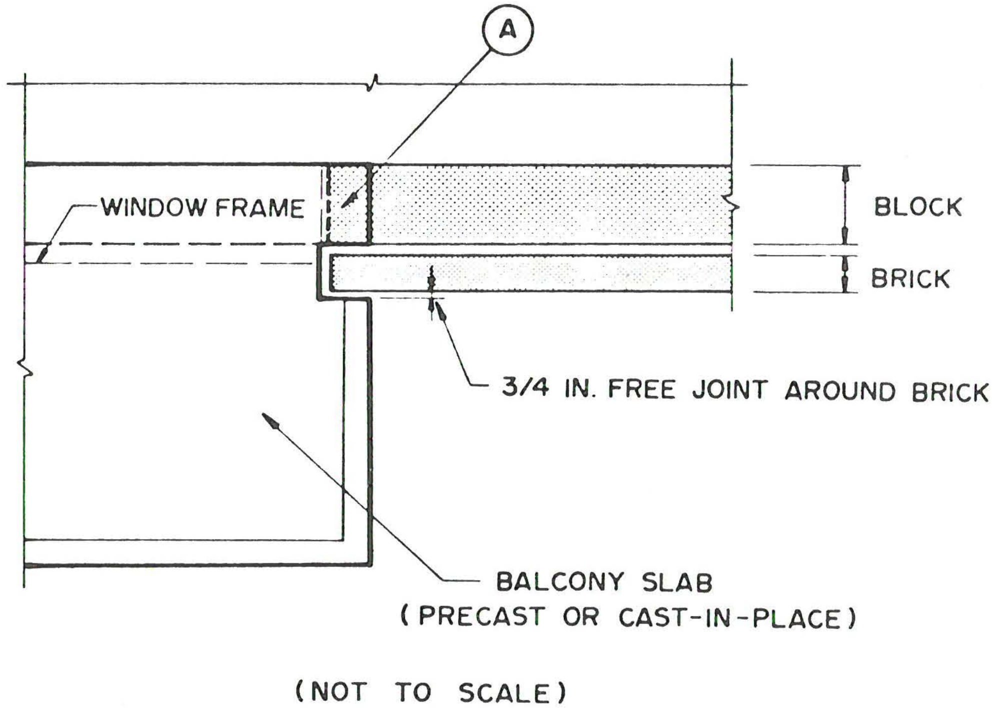


Figure 5 Balcony Supported On Blockwall

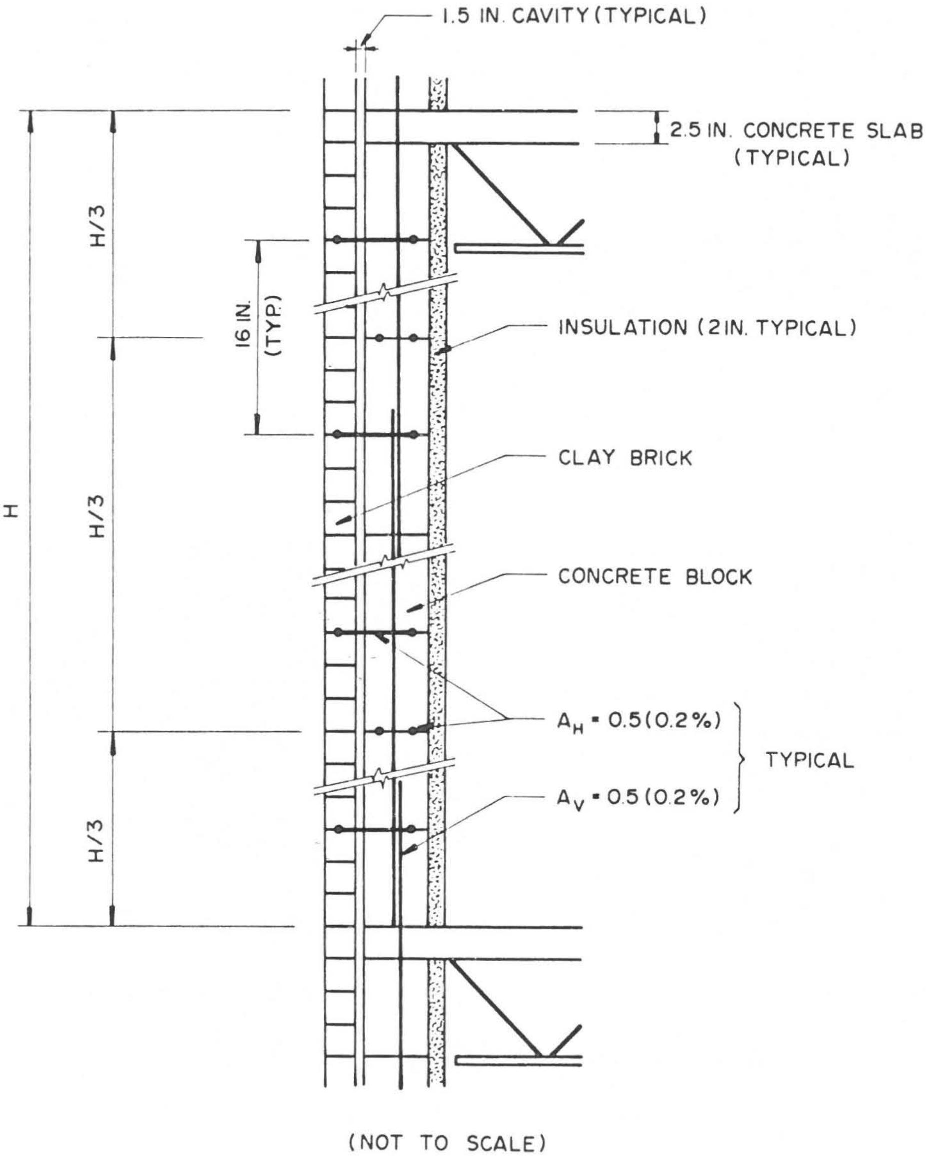


Figure 2 Typical Exterior Wall Assembly

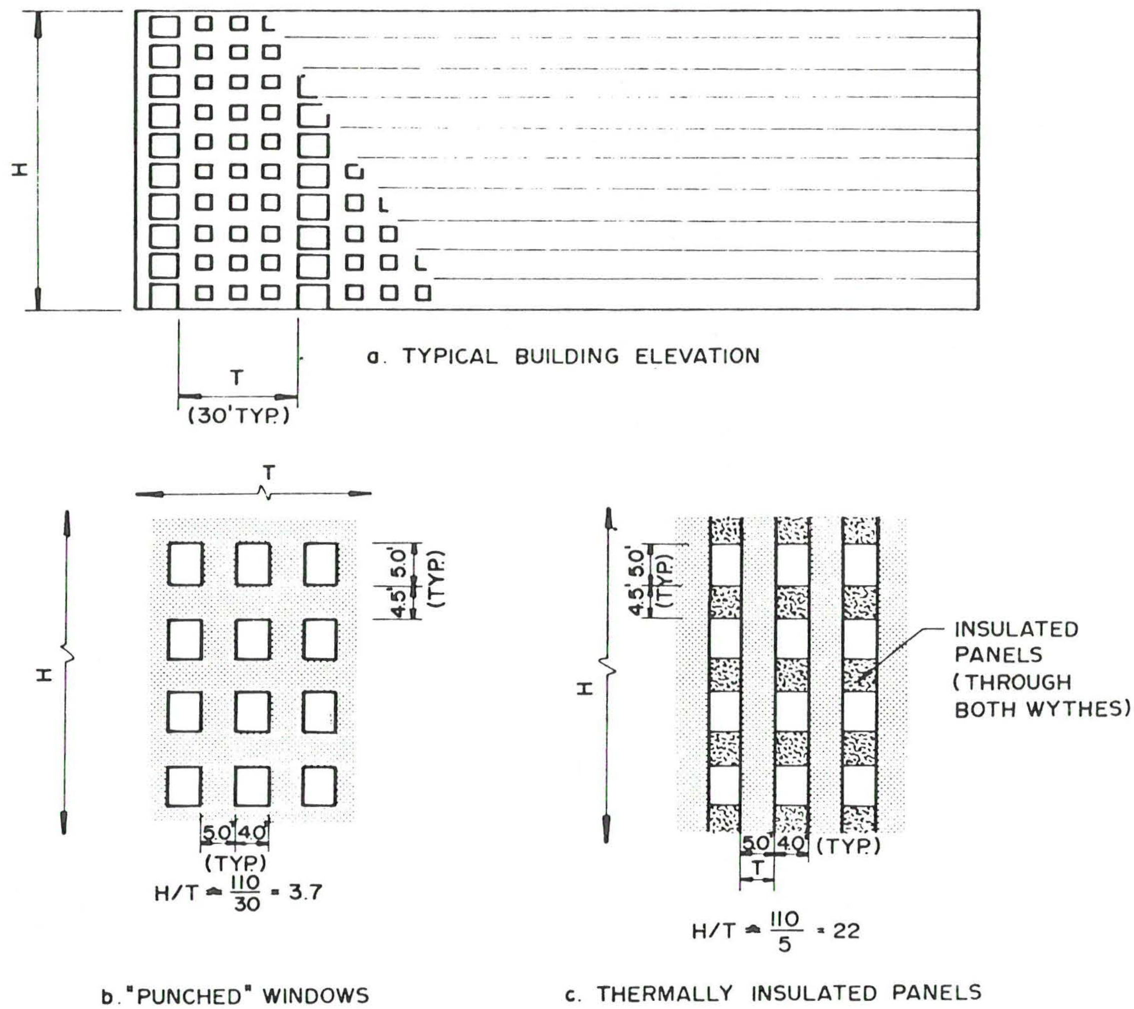


Figure 3 Commonly Used Window Arrangement

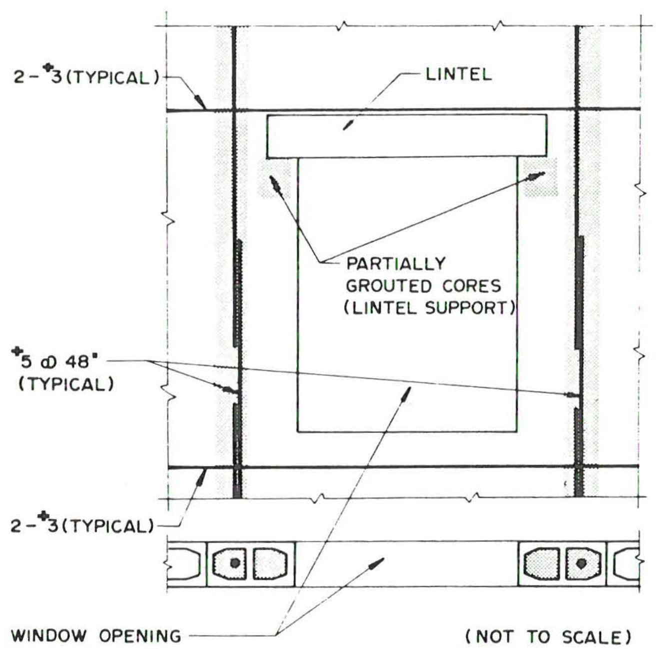


Figure 4 Typical Reinforcement Around Window

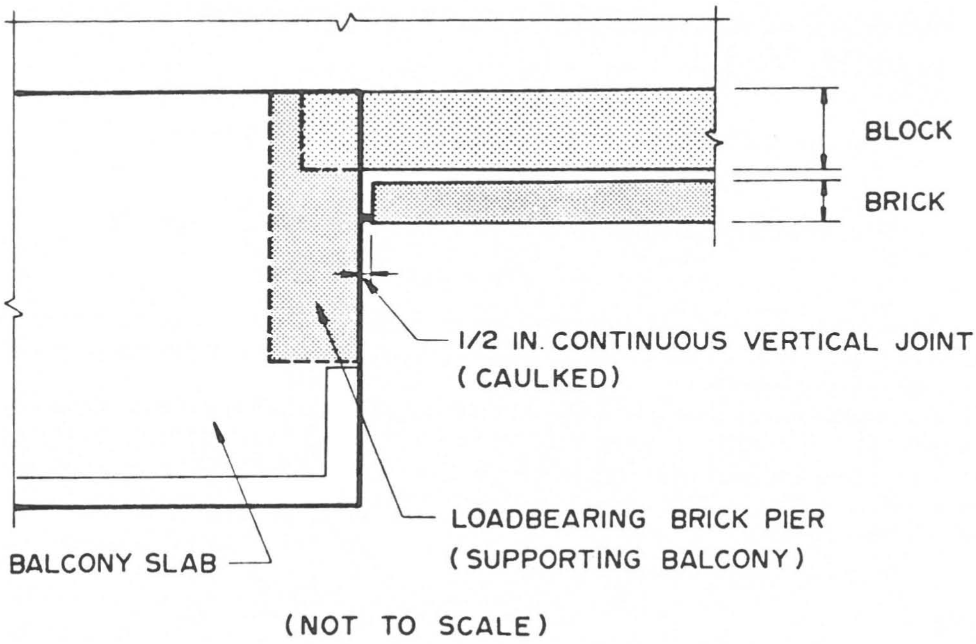


Figure 6 Balcony Supported on Loadbearing Brick Piers

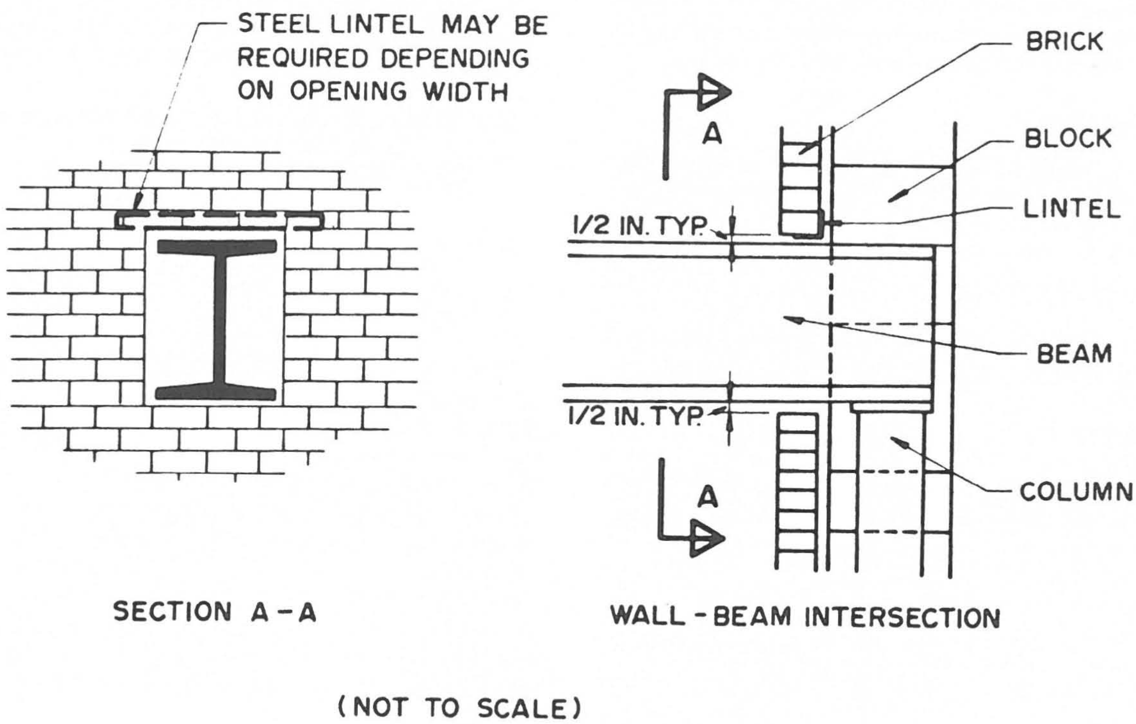


Figure 7 Steel Beam Projecting Through Veneer