Technical Notes on Brick Construction

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

27 REVISED

August 1994

BRICK MASONRY RAIN SCREEN WALLS

Abstract: Pressure equalization across the exterior wythe of brick veneer and cavity walls allows the rain screen principle to minimize the infiltration of rain into exterior walls. This *Technical Notes* focuses on the design and wall components that contribute to the pressure equalized rain screen wall. A compartmented air cavity behind the exterior brick wythe, a rigid air barrier system and adequate venting area of the exterior cladding in relation to the leakage area of the air barrier are necessary elements.

Key Words: air barrier, air retarder, brick veneer, cavity wall, drainage wall, exterior cladding, pressure equalization, rain screen, wind loads.

INTRODUCTION

Rain penetration through walls can damage the building envelope. Corrosion of metal accessories in the exterior cladding, efflorescence of the masonry and damage to interior finishes and staining are just a few examples of problems related to moisture penetration. Water penetration affects the appearance and function of a variety of brick masonry wall systems.

Over the years, many methods have been used to prevent moisture penetration of walls, some more successfully than others. Masonry barrier walls rely on the massive wall materials to deter water penetration. Drainage type walls, such as brick veneer and cavity walls, provide good moisture penetration resistance. It must be recognized that the exterior wythe can not be made watertight. Provisions for internal drainage are necessary for these wall systems to function as intended.

The next step to provide better moisture penetration resistance for exterior brick walls is the use of the rain screen principle. This concept introduces air into the cavity of conventional drainage type walls to provide pressure equalization so that the cavity works in resisting wind-driven moisture penetration.

Cladding researchers and investigators increasingly recognize air pressure as a major cause of water penetration problems. They are looking more carefully to the rain screen principle as a deterrent to moisture penetration. This *Technical Notes* discusses the design criteria of the rain screen wall, how to develop the pressure equalization feature within the cavity space and additional construction detailing needed to tailor conventional brick veneer and cavity wall systems to the pressure equalized rain screen principle. Other *Technical Notes* in this series will address construction considerations and material selection.

HISTORY

The rain screen principle has been used intuitively for many years. One of the first references to it was made in 1946 by C. H. Johansson entitled, "The Influence of Moisture on the Heat Conductance for Brick". It was not until sixteen years later that researchers began to understand how to apply the fundamental laws of physics to the development of the rain screen principle for practical use.

In 1962, Birkeland of the Norwegian Building Institute wrote Curtain Walls in which he stated:

"The only practical solution to the problem of rain penetration is to design the exterior rainproof finishing so open that no super-pressure can be created over the joints or seams of the finishing. This effect is achieved by providing an air space behind the exterior finishing, but with connection to the outside air. The surges of air pressure created by the gusts of wind will then be equalized on both sides of the finishing. "

Birkeland noted six main sources of moisture leakage through wall systems. The processes discussed were: 1) wind-induced air pressure differences; 2) pressure assisted capillarity; 3) gravity; 4) kinetic energy; 5) air currents; and 6) updrafts. Conventional means such as internal wall flashing, proper design of openings and overhangs provide moisture resistance to items 2 through 6. But item 1 was the most difficult to counteract. He concluded that there was no practical method of obtaining total watertightness in wall systems composed of joints when a pressure gradient exists across the exterior rain barrier. These observations formed the basis of the rain screen principle.

Prompted by Birkeland, researchers in Canada began an intensive study into wall leakage. In 1963, Canadian Building Digest (CBD) 40, "Rain Penetration and Its Control" was published by the Canadian National

Research Council's Division of Building Research. This publication. which remains a prime reference source on the subject, popularized the term rain screen principle. G. K. Garden, who authored CBD 40 on wind-induced moisture penetration wrote:

"It is not conceivable that a building designer can prevent the exterior surface of a wall from getting wet nor that he can guarantee that no openings will develop to permit passage of water. It has, however, been shown that through-wall penetration of rain can be prevented by incorporating an air chamber into the joint or wall where the air pressure is always equal to that on the outside. In essence, the outer layer (wythe) is then an open rain screen that prevents wetting of the actual wall or air barrier of the building".

The critical features of the rain screen principle are:

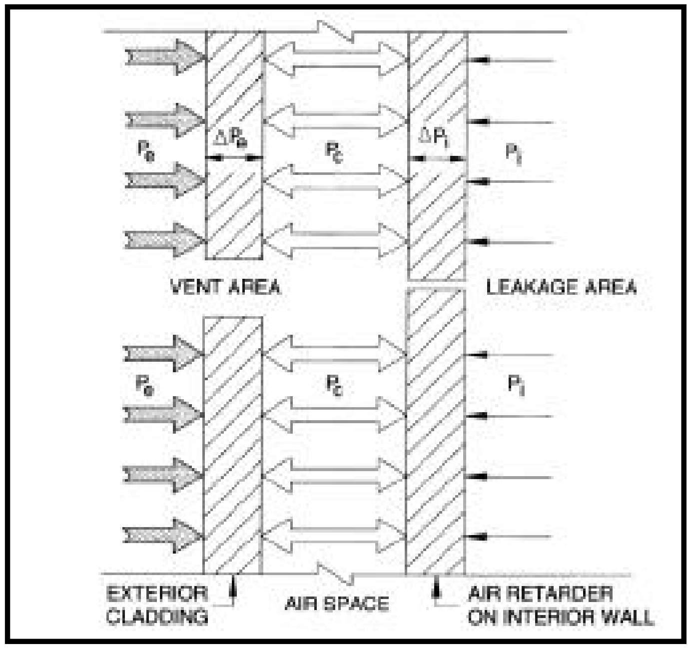
1. An exterior barrier (rain screen) containing protected openings which permit the passage of air but not water.
2. A confined cavity behind the rain screen in which air pressure is essentially the same as the external air pressure.
3. Insulation fixed to the outer face of the interior wall system, if provided in design.
4. An interior barrier (wall) which substantially limits the passage of air and water vapor and is capable of withstanding all required design loads (e.g. wind and earthquake forces).

Many field studies and laboratory tests have applied this principle to a variety of wall systems, including masonry. The developments made over the years can be effectively applied to conventional brick masonry drainage wall construction, with some modifications as discussed in this *Technical Notes*.

DEFINITION AND PRINCIPLES

Drainage wall types, such as anchored brick veneers and cavity walls, which provide a space for drainage of moisture that has penetrated the exterior wythe, are often confused with rain screen walls. When causes of rain leakage problems are debated, the question usually arises of whether the wall system utilizes the rain screen principle. Certainly, there is a cavity between the exterior wythe and interior wall which provides drainage of moisture which has entered the wall. The concept of drainage type walls has been around for decades. More information on brick veneer and cavity wall systems can be found in *Technical Notes* 28 Series and 21, respectively. However, the basic premise of the rain screen principle is to control all forces that can drive moisture through the wall system.

The term **pressure equalized rain screen wall** should be used. This emphasizes the difference from the more common drainage type wall. The pressure equalization in the cavity behind the exterior wythe is the major difference between a rain screen wall and a drainage wall. A pressure equalized rain screen wall provides the best means of resisting water penetration. As such, it should be used on projects located in areas which receive high volumes of wind-driven rain and when resistance to water penetration is of prime concern.

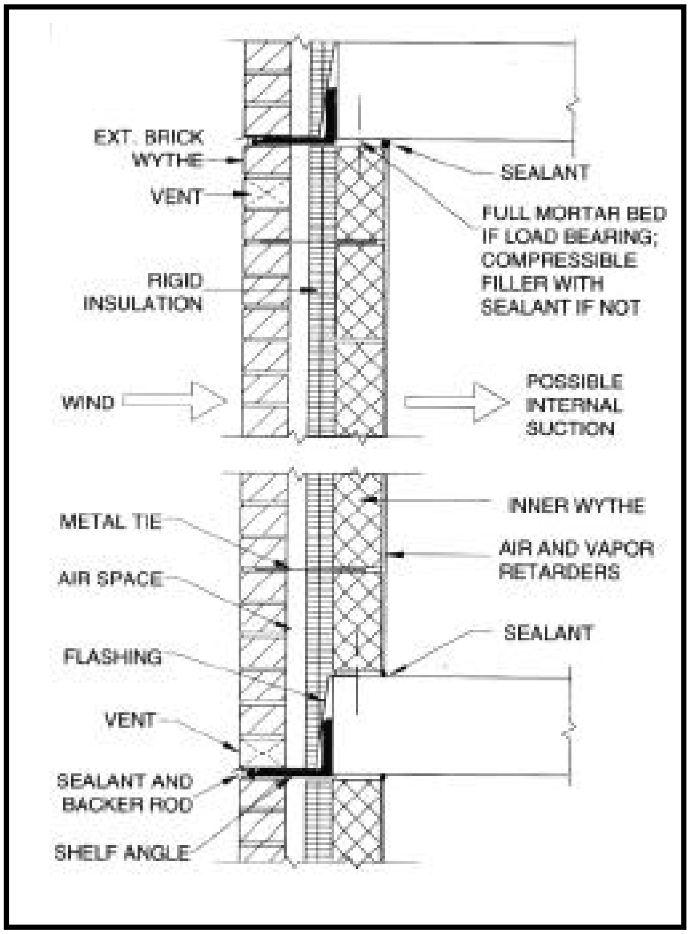


Rain Screen Wall Principle
FIG. 1

Pressure Equalized Rain Screen Walls

The difference in air pressures across the exterior cladding is a significant force which causes infiltration of air and water on windward facades. Air and moisture can infiltrate through units, mortar joints, hairline cracks, poorly bonded surfaces and other openings that exist or develop over the life of the structure.

A rain screen wall is composed of two layers of materials separated by a cavity as shown in Figure 1. The exterior cladding as discussed in this *Technical Notes* is a brick masonry wythe. The interior wall or inner layer can be either the backing of an anchored brick veneer wall or the inner wythe of a cavity wall. When wind loads are imposed on the wall assembly, a pressure difference between the exterior wythe and the cavity space is created. This pressure difference forces water on the surface of the exterior cladding to penetrate any openings through the wall. If the exterior cladding has sufficient openings to permit air to flow to the cavity behind the cladding, the pressure in the cavity increases until it equals the pressure resulting from the wind load being applied. This is the phenomenon of pressure equalization design. To affect this air pressure transfer, the inner layer of the wall assembly must be airtight. This is achieved by applying an air retarder at some location on the backing or inner wythe. The air barrier seal at this location should last longer because it is not exposed to the exterior elements. Since the interior wall will be airtight, stack effect and mechanical ventilation generated inside the building are effectively controlled. Rain penetration through the exterior cladding should be reduced as the pressure difference on the exterior cladding which drives rain into the cavity is reduced. The resultant wind load will be imposed on the air barrier and interior wall.



Brick Rain Screen Wall
FIG. 2

Moisture Migration

Exterior claddings primarily restrict the passage of water and wind and also function as part of a thermal barrier. The extent to which the exterior cladding can be relied upon to serve these functions is variable, and the exterior cladding is not considered to be the sole air or moisture barrier in the wall system.

Rain screen walls using brick veneer and cavity wall systems should be designed as a two-stage barrier for moisture penetration resistance. The first stage is the exterior brick wythe. The backing assembly or the inner wythe is the second stage. The exterior brick wythe should be detailed and constructed to provide moisture resistance so that the second stage is not continually tested. If excess water penetrates the exterior brick wythe, the backing system may become a single stage in itself which can lead to failure of the rain screen principle as a whole. A typical brick masonry rain screen wall is shown in Fig. 2.

The exterior brick wythe is the first stage of the rain screen principle, and a majority of the rain water will run down the face of the brickwork. Some moisture in contact with the exterior wythe is absorbed by capillary action. If wind pressure is applied to the face of the exterior brick wythe, the moisture will be forced into the brickwork, particularly at mortar joints or openings. The use of dissimilar materials, the presence of mortar joints and the variations of workmanship make it difficult to ensure a fully waterproof exterior wythe. Some moisture will penetrate the brick wythe and infiltrate into the cavity space. If the cavity space is at the same air pressure as the exterior as a result of air flow through vent openings and weep holes, the only moisture which will reach the cavity space is due to gravity flow and capillary action. For the rain screen principle to work effectively, water which penetrates the exterior brick wythe travels down the interior side, is collected on flashing and transferred to the exterior through weep holes.

It is not advisable to support the exterior cladding on the floor assembly with the backing system. If detailed in this manner, moisture which penetrates the exterior cladding and its flashing has direct access through the joint at the base of the interior wall to the interior of the building. Moisture can also flow under the flashing and penetrate directly into the building. To avoid the chances of moisture penetration at this location, the exterior cladding support should be lower than the support of the interior wall.

The rain screen principle relies on the use of intentional openings in the exterior brick wythe to create pressure equalization in the cavity. The cavity pressure should be close to the external pressure. That depends upon the air leakage characteristics of the exterior brick wythe and that of the air retarder on the backing or the inner wythe. Sufficient openings in the exterior wythe to balance air pressures with the exterior of the wall system create the pressure equalized rain screen wall. The openings are created by the use of weep holes and vents. Vents near the top of the wall help permit air circulation through the cavity which helps in drying out the wall system.

For the second stage to work effectively, both pressurization of the cavity and the provision for an airtight barrier are extremely important. The extent to which the cavity can be pressurized will reduce the amount of moisture carried through the exterior wythe by wind. It also tends to decrease the tendency for moisture that penetrates due to capillary action to bridge the cavity and contact the backing.

Moisture may actually be transported through the wall system by air passing through weep holes and vents. Movement of air within the cavity can transfer moisture to the interior wall and distribute it along the wall area. Air leakage can then draw this moisture into and through the backing or inner wythe. Laboratory tests have shown that high air leakage through the backing or inner wythe can even cause moisture to climb up and extend the area of wall wetness. The backing or inner wythe should not permit air leakage to occur, thus vents will not have to be oversized which could permit excess rain penetration.

Vapor and Air Retarders

There has been much confusion in the building industry about the functions of vapor and air retarders. Vapor retarders are intended to control transmission of water vapor through building materials. A vapor retarder always serves as an air retarder. Air retarders limit the amount of air flow through wall assemblies. An air retarder may or may not serve as a vapor retarder. It is difficult that either retarder performs only one function. For example, polyethylene film is commonly used as a vapor retarder but will also act to resist the passage of air. Most types of sheathing used as air retarders tend to permit the passage of water vapor. This can result in a common problem: many wall systems essentially have a two-stage setup of retarders.

In actual construction, this means that moisture may become trapped between the air and vapor retarder installations if both are provided at different locations in the wall assembly. The amount of moisture and the duration of wetness of certain critical elements may render the wall design vulnerable to premature deterioration and distress. Of concern is the potential for corrosion of metal accessories within the wall system, deterioration of sheathing materials and decrease in insulation capacity.

Vapor retarders are normally placed on the warm side of insulation in the wall assembly. Air retarders on the other hand have no distinct position. If interior wall board or other finishes are used as retarders, concern arises over punctures for utility services and wall hangings. Further, the incomplete seal around the perimeter of the wall section, may render the air retarder ineffective. The use of the air retarder on the exterior side of the interior wall has additional liabilities. Inspection for proper installation may be difficult and corrective repair may be troublesome. When air exfiltration does occur, the exterior applied air retarder which has some vapor retarder qualities, may result in condensing water being trapped in the wall. Walls designed with rigid insulation on the exterior side of the air retarder can be designed so that the second (partial vapor retarder) barrier is at a temperature above the dew point so condensation problems can be eliminated.

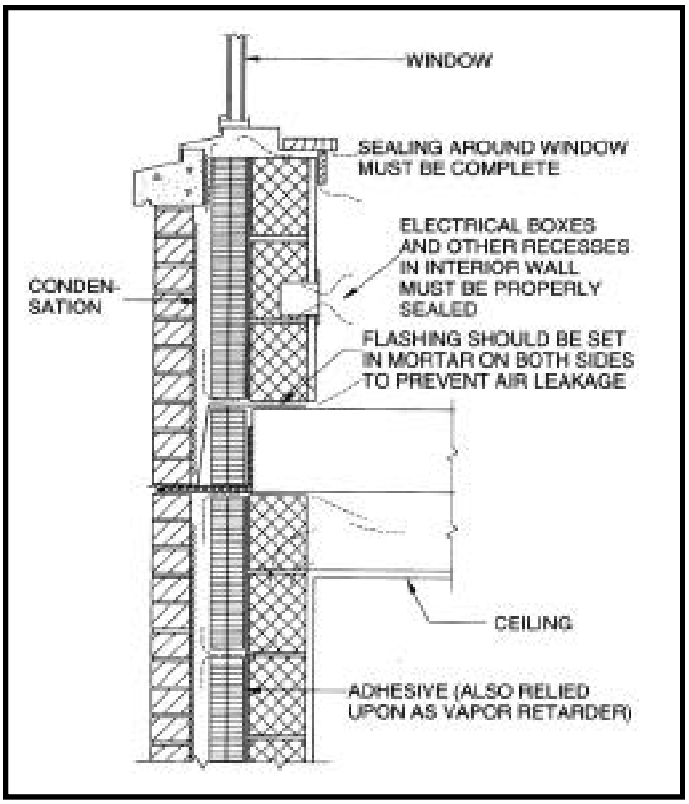
Generally, the mass of water which can penetrate into a wall assembly by air leakage, even through a very small opening, is several times larger than the amount of water which infiltrates by other means. When this airborne water condenses, it is unlikely that it can be removed by vapor transmission or evaporation to the exterior. Drying out of this water is more likely to occur by air moving through the wall system under different temperature and humidity conditions.

The location of the air and vapor retarders will depend on the wall system in question and whether inspection is needed during construction. Construction not requiring inspection should have the air and vapor retarders placed on the interior side of the interior wall. Incorrect installation or faults can easily be repaired or maintained. Where inspection is employed on a project, the air and vapor retarders can be installed within the wall system. However, the long term performance is questionable because these installations are not easily accessible for repair.

When detailing for both air and vapor retarders in pressure equalized rain screen walls, the following should be accounted for:

1. wall openings,
2. disruption of the retarders due to building services such as utilities,
3. concealed spaces such as areas above suspended ceilings, behind heating elements and at junctions of interior walls which connect with outer portions of the building envelope,
4. minimize and seal joints of interior finishes,
5. minimize and seal joints between interior finishes and interruptions such as interior partitions and wall openings.

Most difficulties with installing the retarders occur at wall openings. A variety of materials intersect in one area, which can be complicated. Damage by subsequent trades may breach or puncture the air and vapor retarders. Openings must permit field construction tolerances which must be accommodated by field-fit and sealing of the retarders. Also, attention to details of the air and vapor retarders can help minimize direct heat loss and other detrimental effects due to exfiltration of air movement within the wall system. Figure 3 depicts the possibilities of exfiltrating air in wall construction. Air can circulate through spaces between studs and cells of masonry units and exit at leakage paths to the exterior. Where the components of a building assembly can be completely sealed to prevent air leakage and the interior finish material provides the vapor resistance needed, a separate vapor retarder is not usually required.



Sources of Exfiltrating Air Movement
FIG. 3

To provide effective air and vapor retarders, it is necessary to seal joints in these materials so that continuity is provided. It is also necessary to seal around the edges of wall openings such as windows, doors and access for utility services. Caulking or taping of the joints should be specified. The joints in the retarders should be detailed and dimensioned with consideration of the need to accommodate variations in joint dimensions, building deflections and differential movement of building materials.

If the sealant materials are inaccessible after construction, they must have qualities which will provide satisfactory performance over the life of the structure. Even when the sealant material can be repaired or replaced, the sealant must be suitable for the construction materials and environmental conditions. Field experience, tests or manufacturer's literature should be used as the basis for selecting sealant materials for compatibility with the air and vapor retarders selected.

The successful performance of the joint seal over the life of the structure depends on the ability of the material to adhere to the surfaces and to deform without tearing, delamination or peeling under repeated cycles of expansion and contraction. Workmanship is also very important. Air bubbles in the sealant or air voids between the sealant and adjacent materials must be avoided. Sealant manufacturer's information should be followed for proper installation.

Axial and Lateral Loads

Load application to the exterior brick wythe and the interior wall and load transfer are based on the type of wall design and its associated construction. The exterior wythe is treated differently in cavity wall design from that in veneer wall design. The treatment of the exterior wythe of a rain screen wall with respect to axial and lateral loads is no different from that of conventional construction.

The exterior wythe of a veneer wall should not be subjected to any axial load other than its own weight. Veneers must be designed, detailed, and constructed so that no axial loads are imposed. The exterior wythe of a cavity wall can carry vertical loads and still perform as the exterior cladding in the rain screen wall. The imposed load depends on the anchorage of floor or roof components to the exterior wythe.

Building codes state that the brick wythe of an anchored veneer wall does not resist lateral loads and that the backing must be designed to carry all lateral loads. In cavity wall design, both wythes share a portion of the lateral loads imposed. In fact, all lateral loads will initially be resisted by the exterior wythe and then transferred through the wall system to the building frame. For lateral load distribution to occur, the exterior wythe must be anchored to the backing or interior wythe with metal ties in a sufficient number and spacing. Design must consider lateral load distribution, tie stiffness and deflection of the wall system. See *Technical Notes* 21 Series and 28 Series for the proper design and construction of cavity walls and brick veneer over wood or steel backings, respectively.

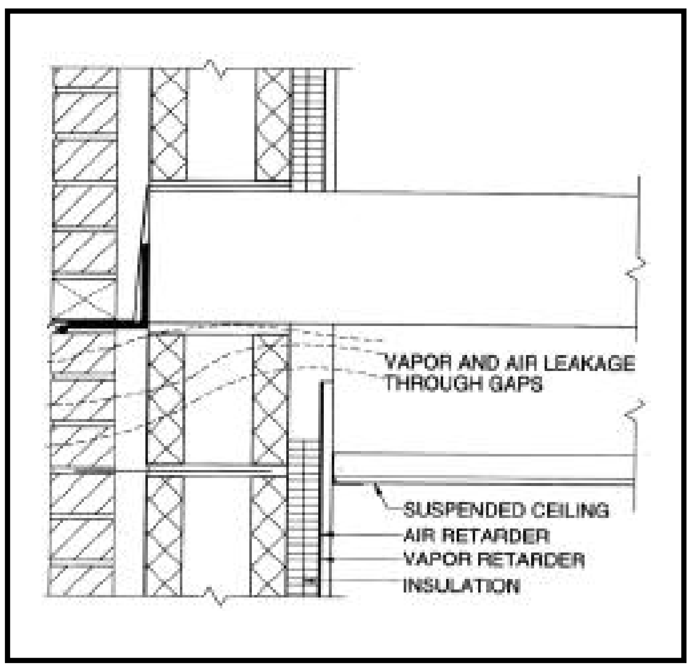
Thermal Insulation

All wall components affect the thermal resistance of the assembly and contribute to the overall R-value. For masonry wall systems, the insulation provides most of the thermal resistance. The designer should choose the level of insulation required as part of the total wall design, considering its location.

The type and location of the insulation has a significant impact on the design and installation of the air and vapor retarders. The possible locations for thermal insulation include: 1) in the cavity; 2) in the interior wall; and 3) on either face of the interior wall. The general types of insulation used in drainage type walls are rigid board insulation, fiberglass (batt) insulation or loose fill.

It is important to eliminate any gap between the insulation and the floor or ceiling. With suspended ceilings or ceilings attached to the bottom chord of joist construction, the insulation should be continued above the ceiling to the bottom of structural slabs, not as detailed in Fig. 4. For the pressure equalization to occur, air and vapor retarders must also be continued to the floor or roof above the suspended ceilings. If the air retarder is not continued, the insulation may separate from the backing wall by air infiltration pressure. Proper abutment of the edges of the insulation must be considered to hinder air circulation from the interior of the building.

Cavity Placement. Rigid board insulation should be used when insulation in the cavity is desired. In order to be effective, it must be adhered tightly to the exterior side of the interior wall. If any air is permitted to circulate behind the insulation, the pressure equalization of the cavity is weakened as is the insulation capacity. As a result, the method of securing the insulation is important. Generally, adhesives or mechanical fasteners are used. Consideration on selecting adhesives includes: 1) assur-



Leakage Above Suspended Ceilings
FIG. 4

ing clean surfaces under field conditions; 2) compatibility of the adhesive with the insulation; 3) long-term effectiveness of the adhesive; and 4) movement of the wall system.

Use of dabs of adhesive is not recommended because it creates an air gap which allows free air movement. Use of a full adhesive bed is recommended, where the full adhesive bed acts as a vapor barrier. If a full adhesive bed is not desired, a grid set-up is recommended because it will compartmentize the air spaces behind the insulation board and retain the full insulation capacity.

There are a variety of mechanical fasteners available to attach rigid board insulation to the backing wall. Use of mechanical fasteners is suggested where uneven surfaces or protrusion of mortar require bending of the insulation to avoid air-gaps between the insulation and the interior wall. Mechanical fasteners are more reliable in the long term than adhesively attached clips. Adhesively attached fasteners are more convenient, but the same considerations for selecting adhesives to attach the insulation must be evaluated. Mortar joints should be cut flush to remove fins or protrusions and provide as smooth a surface as possible for a tight fit of the insulation to the interior wall.

The insulation must support its own weight and accommodate expected wall movements. Further, the insulation may be subjected to wind pressures. These wind pressures must be resisted by the insulation to avoid separation of the insulation from the interior wall. The choice of mechanical fasteners, adhesives or a combination of both should take into consideration the life of the structure, conformance with manufacturer's specifications and possible failure of the fastener or adhesive. Thus, in some cases a combination of both may be advisable to ensure that costly repairs are not needed for the life of the structure.

Loose granular fill insulation must not be placed in the cavity. This placement violates the rain screen principle. However, loose fill insulation, such as vermiculite and perlite, can be used in the unobstructed vertical cells of the masonry backing to increase thermal resistance.

Stud Wall Placement. For stud wall backings, fiberglass (batt) insulation is placed in the stud cavities. The insulation is usually slightly larger than the stud depth to provide a friction fit. Stud spacing should be controlled so that friction will be effective in keeping the insulation in place. The fiberglass insulation must fill the entire stud cavity so that air circulation is minimized. If not completely filled, convection can greatly reduce the thermal resistance of the interior backing wall.

Interior of Wall Placement. Insulation installed on the interior of the interior wall is usually limited to masonry backings. It provides easy installation and is available to inspection of placement. The insulation can be applied by many means, but the need to support interior finishes usually requires the use of metal or wood furring.

Differential Movement

All building materials change dimension with changes in temperature. Some building materials change dimension with moisture content. All materials will deform elastically when subjected to loads. Some materials with cement matrices will deform plastically (creep) when loaded. Adequate allowance for deformations of materials and building movements are critical to the successful performance of the pressure equalized rain screen wall. Problems can arise if these naturally occurring movements are not recognized and accommodated for in initial design. The air and vapor retarders must not be disrupted by building movements, whether it be material generated or the building as a whole.

Sealing of movement joints is required to prevent the passage of water and air without restricting differential movement. The sealant acts as the primary resistance to the passage of water through joints in exterior elements. A backing material and, perhaps, a filler may be needed for large movement joints.

Discussion of building movements is beyond the scope of this *Technical Notes*. The reader is directed to *Technical Notes* 18 Series for information on accommodating material and building movements, such as the building frame, exterior cladding and interior wall systems. Recommendations for other materials should be reviewed.

PRESSURE EQUALIZED RAIN SCREEN DESIGN PARAMETERS

The pressure equalized rain screen wall, whether a brick veneer or a cavity wall system, will be subject to both axial and lateral loads. In the design of these innovative wall systems, imposed loads must be taken into account for the rain screen wall to perform as intended. Other environmental loads, such as moisture leakage, thermal and air retarder performance, must also be considered. There are many parameters which affect the pressure equalized rain screen principle. These parameters include: 1) rate of applied wind load; 2) magnitude of applied wind load; 3) cavity volume; 4) stiffness of the interior wall and the exterior cladding; 5) compartmentation of the cavity; and 6) leakage areas of the air retarder and the exterior cladding. Many of these factors are interrelated.

Wind Loads

An advantage of the pressure equalized rain screen wall, in theory, is that no wind load should be imposed on the exterior cladding. However, wind is dynamic and variable so that the pressures applied to the wall are constantly changing. An ideal rain screen wall would pressure equalize instantly. In fact there is a time lag between the imposed wind load and pressure equalization in the cavity. As a result a pressure difference does occur across the exterior cladding.

This pressure is normally positive, a driving force pushing air into the wall. However, the cavity pressure can exceed the positive wind pressure under gusting wind conditions. This situation occurs after the cavity pressure increases to match that of a high wind, and the wind suddenly decreases. Until pressure equalization occurs, the cavity pressure will exceed the exterior wind pressure which creates a negative load on the cladding. This negative loading will tend to force water out of openings in the exterior cladding, reducing the likelihood of further moisture penetration. Under the rain screen principle, wind loads on the exterior brick wythe may actually be reduced due to pressure equalization of the cavity space. However, the entire design wind load should be applied to the exterior cladding and the backing.

Pressure Differences and Distribution

Pressure differences are encountered in buildings from two main sources. The first is commonly referred to as stack effect, which is created by temperature differences between the exterior and interior of the building. The second is the wind forces that are imposed on the building envelope. The net pressure difference across a wall system at the top and sides may be a combination of both and is not the same for all parts of the building envelope.

The stack effect which occurs mainly during the heating season results from warmer inside air rising as a result of a lower density than cooler outside air. This difference in density creates an outward positive pressure at the top of a building, while exerting negative pressure at the wall base. Thus, air will tend to infiltrate at the lower levels of the building and exfiltrate at the upper levels.

Wind causes air infiltration on the windward side of buildings and exfiltration on the leeward side and also on the sides parallel to the wind direction. A flat roof will experience exfiltration because of negative uplift pressure caused by wind. Since wind velocity increases with height, the difference in pressure across the building envelope increases with height.

Pressure distribution on the windward facade varies from a maximum at the center and decreases towards the corners of the building. Suction pressures on the leeward wall vary from a maximum at the corners of the building, diminishing towards the center. The pressure on the side walls parallel to the wind direction is normally negative, but may change rapidly to positive pressure as the wind changes directions. This is usually why wind pressures are normally higher at the top and corners of the building envelope.

The rain screen wall minimizes the air pressure differences across the exterior brick wythe by transferring the pressure to the cavity space, see Fig. 1. Under the imposed wind load (P_e), air flows into the cavity causing the cavity pressure (P_c) to increase until $P_c = P_e$ and $\Delta P_c = 0$. When the entire wind load is imposed on the interior wall, pressure equalization will occur. The veneer backing or the interior cavity wall wythe is thus designed for the entire wind load.

Cavity Volume

When positive pressure is applied to the exterior cladding, movement of air into the cavity causes the pressure in the cavity to increase to match the external pressure applied. The volume of air required to achieve pressure equalization is dependent on the volume of the cavity. The rate at which pressure equalization occurs is dependent on the rate at which air can enter the cavity. Thus, as the cavity volume increases, the vent openings in the exterior brick wythe must be increased in order to permit more rapid pressure equalization. The driving force causing air to enter the cavity is the pressure difference across the exterior cladding. As air enters the cavity, this pressure difference decreases. The flow rate is proportional to the pressure difference, and as air flows into the cavity, the flow rate decreases.

Both the exterior cladding and air retarder applied to the interior wall will deflect under applied loads. Stiffness of these elements will influence the volume of the cavity. Since these deflections also vary as the pressure differences vary, it becomes clear that this situation is very complex.

Leakage of the Exterior Cladding and the Air Retarder

The relative airtightness of the exterior cladding with respect to that of the air retarder applied to the interior wall is paramount for the cavity to pressure equalize with the exterior wind pressure. If the two layers have similar air leakage characteristics, each layer will transmit the same volume of air, and the pressure differences will not change. If the interior wall is made more airtight, a greater pressure difference will occur across it than that across the exterior cladding. In the ideal case, the air retarder would be completely airtight, and the pressure difference across the exterior cladding would be negligible. However, this is generally not the case.

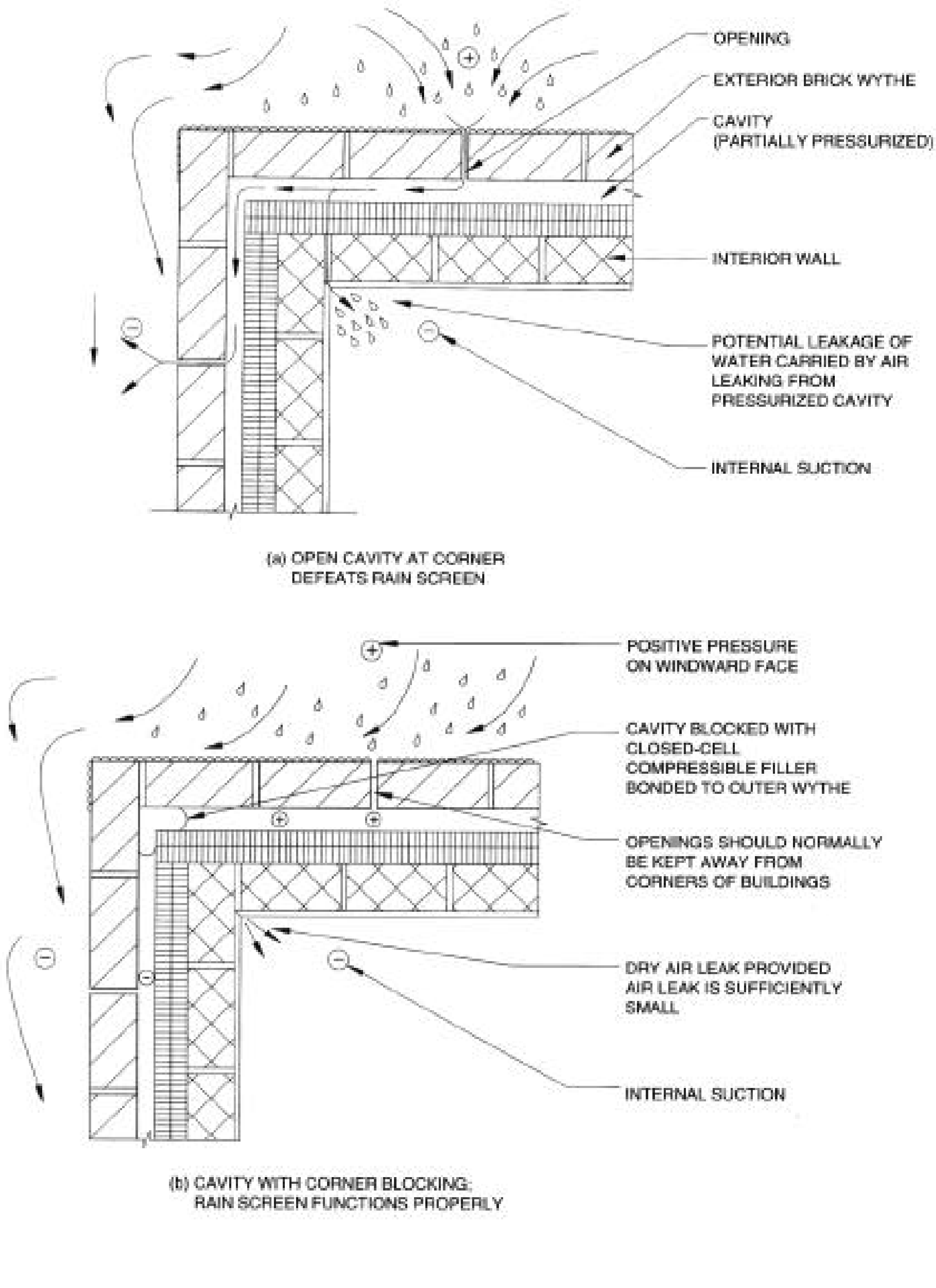
The effectiveness of the rain screen wall is decreased as greater amounts of air are permitted to penetrate through the air retarder. The Architectural Aluminum Manufacturers Association specifies that, for laboratory tests, air leakage through a curtain wall should not exceed 0.06 cfm/ft^2 (0.0003 m^3/s/m^2) for a pressure difference equivalent to a 25 mph (11 m/s) wind. This value for air retarders is currently being considered in ASTM Committee E 6. However, in Canada, the acceptable rate is one-third of that currently being suggested in ASTM. It seems prudent to use the lower value for air leakage through the air retarder.

Compartmentation

The wind pressure flowing around a building creates a distribution of positive and negative pressures over the building exterior cladding as shown in Fig. 5. If the cavity of the rain screen wall is continuous, horizontally or vertically, lateral flow of air in the cavity will occur.

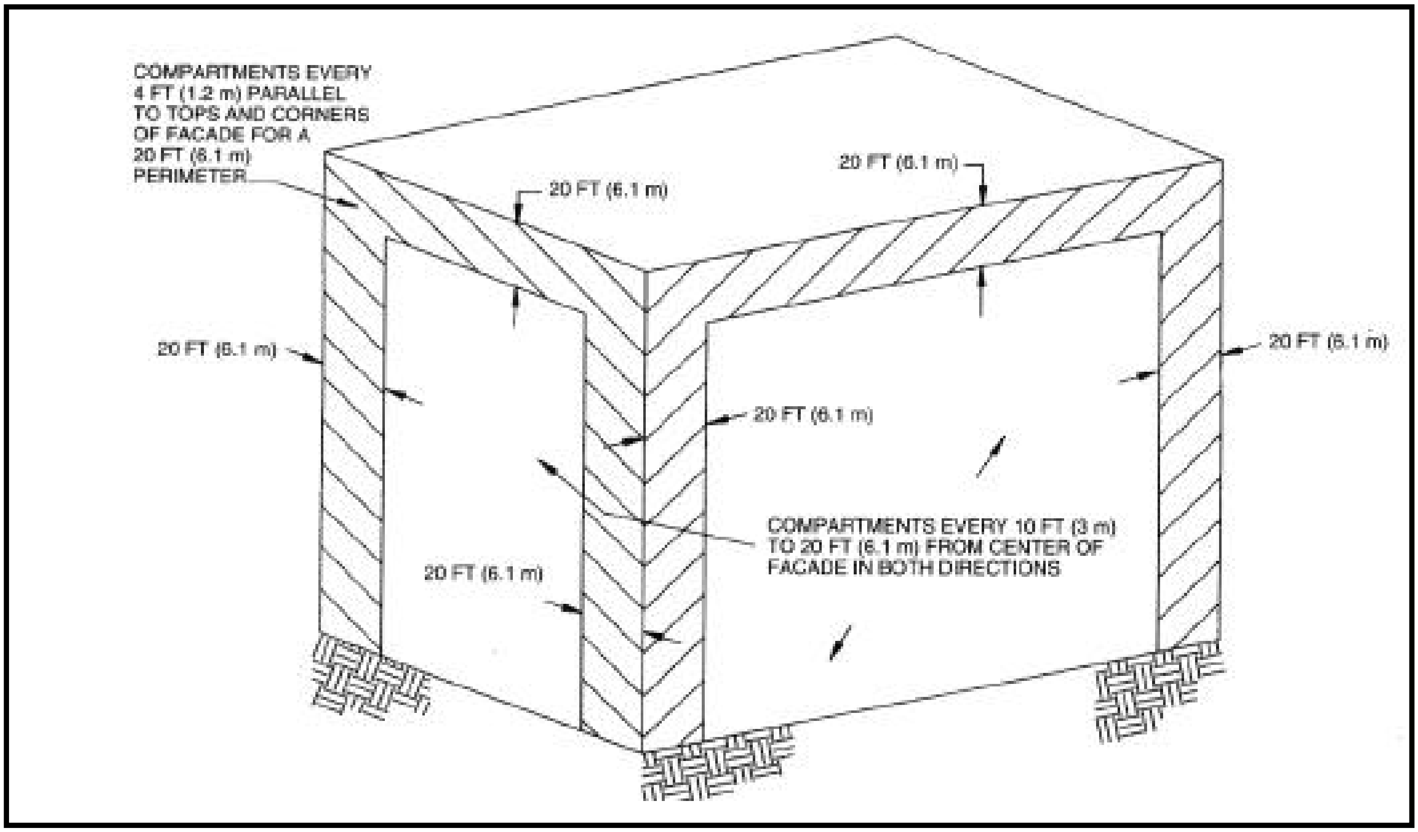
If air is permitted to flow laterally in the cavity, pressure equalization will not occur. Moisture penetration into the wall assembly may not be reduced.

To prevent lateral airflow, the cavity must be compartmented. The size of the compartments should be based on the pressure differences across the exterior cladding. The corners and tops of buildings experience the greatest pressure differences; hence, the compartments located in these areas should be small. Where pressure differences are small, such as the center of the exterior cladding, the compartments can be larger. Many researchers suggest that these compartments have closures no more than 4 ft (1.2 m) apart at the sides and top of the building in a 20 ft (6 m) wide perimeter zone, see Fig. 6. Compartment clo-



Moisture Movement Caused by Wind
FIG. 5

sures should be within this recommendation for the sides and top of the building. Based on the design wind pressure of the wall area in question, compartment dimensions outside the 20 ft (6 m) zone of the tops and corners of the building can be increased. For a design wind pressure less than 15 psf (718 Pa), compartment closures should be provided for every 400 ft^2 (37 m^2) of wall area. When the design wind pressure is between 15 psf (718 Pa) and 25 psf (1200 Pa), the compartment closures should be decreased to 250 ft^2 (23 m^2) of area. When the design wind pressure is greater than 25 psf (1200 Pa),



Compartmentation of Rain Screen Walls
FIG. 6

the compartment closures should have a maximum area of 100 ft^2 (9 m^2). At the minimum, the cavity must be closed at all corners and at the roof to prevent air from the windward side of the building laterally flowing to the adjacent sides, as shown in Fig. 5.

Research conducted by Canada Mortgage and Housing Corporation used wind tunnel testing to determine the effects of compartmentation in the cavity. One significant result of this testing was that the compartment closures experienced at least two times the applied wind load. This research concluded that compartment closures must be designed for high wind pressures and must be completely sealed to prevent lateral airflow from one compartment to the next.

Exterior Cladding Openings

To provide pressure equalization in the rain screen wall, there must be a series of openings to connect the cavity to the exterior of the wall system. The openings should be positioned at the top and bottom of each compartment. All openings at the top and bottom should be placed at the same height, respectively, to avoid airflow loops in the cavity.

There are no definitive guidelines for the required amount of openings for each compartment. The area of openings depends on the airtightness of other components of the cavity, e.g., the air retarder system and the cavity closures. If completely sealed compartment closures are used, a 10:1 ratio for cladding air leakage to air retarder leakage is recommended. Most often, the cavity closures will not form an airtight seal of the individual compartments. To account for this the required opening area should be larger. Some studies suggest a ratio of 25 to 40 times more air flow volume through the openings in the exterior brick wythe than air leakage through the interior wall. Therefore, the tighter the compartment, the less the area of openings in the exterior cladding required for pressure equalization of the cavity. To obtain the airtightness value of the interior wall construction, testing of a mock-up wall compartment may be required since little information on the range of air tightness of various field-applied air retarder components is available. After having evaluated the air tightness of the interior wall, the openings in the exterior cladding should be established to fit the recommended ratio.

The following recommendations should provide sufficient venting to achieve pressure equalization for the rain screen wall. Vents are installed at the top and bottom of each compartment. Open head joints should be spaced at a maximum of 24 in. (600 mm) o.c. horizontally in the exterior brick wythe. If clear, round openings are used, they should be at least 3/8 in. (10 mm) inside diameter, and the spacing should be reduced to 16 in. (400 mm) o.c. horizontally. Open head joints may be positioned at flashing locations in the exterior brick wythe and serve as weep holes. A minimum of two vents at both the top and bottom should be provided for each individual compartment. The suggested minimum cavity width is 2 in. (50 mm). If the cavity space width is greater than 2 in. (50 mm), open head joints should be used as vents. Vents should not be positioned at corners. Water drainage provisions in the wall assembly should be evaluated carefully to avoid placing vents at high flow areas such as sills and heads of openings in the wall system. It is imperative that the cavity have no blockage due to mortar bridging or mortar droppings that can collect at the bottom of the cavity closures in each compartment, thus blocking the vent openings.

SUMMARY

This *Technical Notes* describes the pressure equalized rain screen principle as it applies to conventional brick veneer and cavity wall systems. This innovative wall design has been used extensively in Canada and Europe for many years. Pressure equalization across the exterior wythe of drainage type walls is the main emphasis of the rain screen principle. Design recommendations that cover the prominent aspects of the pressure equalized rain screen principle to minimize rain penetration through the exterior walls are described.

The information and suggestions contained in this *Technical Notes* are based on available data and the experience of the engineering staff of the Brick Institute of America. The information contained herein must be used in conjunction with good technical judgment and a basic understanding of the properties of brick masonry. Final decisions on the use of the information contained in this *Technical Notes* are not within the purview of the Brick Institute of America and must rest with the project architect, engineer and owner.

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