Seventh Canadian Masonry Symposium
McMaster University
Hamilton, Ontario

June 4-7, 1995

COMPARISON OF BACKUP WALLS FOR ANCHORED BRICK VENEER

Case Studies of Building Envelope Systems with Backup Walls of Steel Studs, Concrete Masonry, and Cast-in-Place Concrete

Linda Brock[1]

ABSTRACT

The selection of the proper backup wall is often seen as the prerequisite for a long lasting and low maintenance brick veneer cladding. Using case studies of anchored brick veneer with backup walls of steel studs, concrete masonry units, and reinforced cast-in-place concrete, this paper discusses the relative merits of each in view of economics, constructability, and their role as part of the building envelope.[1]

A continuing debate wages within the professions, industry, and academia over whether steel studs should ever be used as the backup wall. Each side has its proponents and opponents who offer research, statistics, and opinions to substantiate their reasoning. This paper concludes that although a steel stud backup has more associated risks than a concrete or concrete masonry backup, the longevity of anchored brick veneer may be more dependent on proper design, detailing, and construction of the entire building envelope system than on the selection of the material for the backup wall. It is also concluded that the economics of construction in Canada and the United States will likely dictate that steel studs will continue to be frequently selected as the backup for brick veneer.

DEFINITIONS AND ABBREVIATIONS

"Anchored Veneer": A non-load bearing facing that is laterally attached to a structural backup wall.
"Brick": Fired masonry units made of extruded or pressed clay/shale. (This paper does not discuss anchored brick veneer made of concrete facing units.)
"Veneer Anchor Tie": Two piece assembly used to attach veneer to the backup wall. The assembly allows in-plane horizontal and vertical movement of the veneer but NOT lateral movement.
"Veneer Panel": A built-in-place panel of anchored brick veneer separated from adjacent

[1]Assistant Professor, School of Architecture, University of British Columbia, 6333 Memorial Road, Vancouver, British Columbia V6T 1Z2

veneer panels with vertical expansion joints along the sides and a horizontal expansion joint along the top.
"CIP": Cast-in-place Concrete.
"CMU": Concrete Masonry Units.
"SS": Steel Studs.

INTRODUCTION

Although the backup wall for anchored brick veneer can be analyzed theoretically as a separate component, it is best evaluated in the context of the building envelope system. Such an analysis of the backup wall should consider lateral loading, environmental controls, differential movement, constructability, and economics.

Using case studies this paper will evaluate the following backup walls: anchored brick veneer tied to an infill SS backup; an infill CMU backup; and a reinforced, CIP concrete backup. The three cases were selected because the buildings had sustained major brick veneer failures thus allowing for invasive and thorough investigations; they were constructed within the last 30 years; and they used construction materials and methods consistent with many similar systems being built in Canada and the United States today.

CASE STUDIES

The case studies have many similarities. The original designs included a drainage cavity behind the anchored brick veneer to allow moisture to drain to the exterior. The mortar was generally hard - not easily removed with a plug chisel. The brick units appeared to be well made and showed no deterioration other than what would be expected given the conditions.

Case Study A: Anchored brick veneer with steel stud backup wall, University classroom building constructed in 1987. **See Figure 1.**
This two to five story, reinforced concrete frame building was clad with ribbon windows alternating with brick bands approximately 2.5 m [8'] in height. Located in a semi-arid region of the western United States, the design temperatures range from -23 to +35 DC [-10 to +95 DF].[2] Design wind speed is 146 kph [90 mph],[3] and there is minimal seismic activity in the area (Uniform Building Code Zone 1).[4] Moisture problems were noted immediately by the entry of copious amounts of water to the interior of the building after a wind driven rainstorm (estimated to be a ten year storm). The investigation took place within a year of the building being occupied, and remedial work to improve the system was completed prior to the final payment to the contractor.

The backup wall consisted of 152 mm [6"], 18 gage steel studs at 406 mm [16"] on center. The steel stud wall was attached at approximately mid-height to the concrete beams creating a laterally cantilevered wall above and below the beams. Steel angles welded to embed angles in the concrete beam, were in turn, welded to each steel stud. There were poorly welded connections within the stud wall and in the attachment to the structural frame. The steel studs were faced on the exterior with gypsum sheathing and on the interior with gypsum board. The screws attaching this sheathing had no corrosion resistance and some were showing signs of rust after less than a year. The flexibility of the wall was not determined. The shelf angle that carried both the veneer and the ribbon windows was welded to the steel stud backup wall.

The sill of the ribbon windows was supported by the brick veneer panels with the head attached to the underside of the horizontal leg of the shelf angle with powder-driven pins.

As constructed, there were no means of effectively sealing the top of the window at the slip head to the shelf angle. At the time of the investigation, the primary source of visible water entry was at this attachment where the unsealed gap allowed wind driven rain to easily penetrate to the interior. Water had also entered above the base of the drainage cavity due to a mass of mortar droppings that prevented the weepholes from draining. Most shelf angles exhibited some rust attributable to water leakage after construction was completed.

The brick veneer panel was tied to the backup wall with galvanized veneer anchor ties consisting of 5 mm [3/16"] triangular ties and 12 gage strap anchors spaced at 406 mm [16"] o.c. in both directions. The strap anchors, which had no backing plates to prevent crushing of the gypsum sheathing by the triangular ties, were fastened to the steel stud backup with two steel screws with no corrosion protection. Horizontal movement was accommodated with vertical expansion joints spaced at 6 m [20'] on center but none were located at or near corners. Vertical movement was accommodated by the slip head of the window frame.

Kraft paper faced, fiberglass insulation filled the steel stud cavity. There were no additional water, air, or vapour barriers. The cavity between the brick veneer panel and the backup wall was typically 25 mm to 32 mm [1" to 1-1/4"] with a maximum cavity width of 50 mm [2"]. There were extensive mortar droppings, ranging to 46 cm [18"] in depth, and mortar bridges. The mortar droppings were well consolidated and had bonded to the paper face of the gypsum sheathing. Flexible 20 mil PVC flashing meant to protect the shelf angle had been compromised in several ways. It stopped an average of 25 mm to 38 mm [1" to 1-1/2"] back from the face of the brick, and the powder-driven pins attaching the slip head of the window frame to the underside of the shelf angle had protruded through the angle often puncturing the flashing. The flashing was also melted or torn in numerous locations.

It was determined that at the time of the investigation, the SS backup wall was not part of the failure of this system. However the wall had several problems that may have created the potential for future failures given the high lateral loading and continued corrosion of welds, fasteners, and the steel studs themselves.

Case Study B: Anchored brick veneer with a concrete masonry backup wall, College dormitory constructed in 1967. **See Figure 2.**
This six to seven story, brick clad, concrete frame building had infill CMU backup walls. At each floor windows were centered between concrete columns spaced at approximately 3.7 m [12'] o.c. It is located on the east coast of the United States in an area that in the summer tends to be hot and humid while winters are cold and wet. Design temperatures range from -18 to + 32 DC [0 to +90 DF],[2] design wind speed is 129 kph [80 mph].[3] Seismic activity is minimal (Uniform Building Code Zone 1).[4] Considerable cracking and badly rotating corner panels due to horizontal expansion of the veneer, and unstable parapets due to vertical movement of the veneer, were evident prior to our investigation. A temporary stabilization project, including the addition of eight vertical expansion joints and 260 restoration anchors, had been completed by the owner in 1988. Because of increasing lateral movement of the rotating panels, at our recommendation in 1991, protective canopies were built at the entries and fencing erected to keep people away from the exterior of the building.[5] The cladding was later removed and replaced with a panelized exterior insulation and finish system.

The 250 mm [10"] CMU backup wall had no vertical or horizontal reinforcing and the cells of the block were not grouted. There were no dowels fixing the CMU backup to the concrete frame at the top or bottom. The only connection to the frame was at the columns with dovetail anchors randomly spaced, laid in the concrete block, and inserted in a cast-in-place slot in the column. Because of the depression cast into the end of each concrete block there were gaps up to 50 mm [2"] in width between the column and the CMU at the point where the anchors were installed. Shelf angles were attached to the concrete frame at each floor with askew-head bolts in wedge inserts.

The brick veneer was tied randomly and with inadequate spacing to the concrete columns using dovetail anchors. There was little attachment to the CMU backup wall. In many areas the cavity was partially full of slushed mortar in what may have been an attempt to create a collar joint. The CMU wall was not acting as a backup for lateral loads, except in these fully parged areas and then only for positive wind pressure. No horizontal expansion joints were included so as the veneer expanded vertically, the askew-head bolts were lifted in the wedge inserts allowing the angles to move freely in the vertical direction. This movement was such that near the top of the building many of the bolt heads had raised to the extent that they were no longer properly engaged in the wedge pockets. This vertical expansion had badly distorted many of the aluminum window sills, some of which now sloped towards the interior. It also lifted the parapet which forced the brick veneer to span the 1.83 m [6'] width of every window opening at the top floor creating gaps up to 25 mm [1"] between the veneer and the window head. This caused stresses the veneer was incapable of supporting with the result that many of these "arches" had cracked at the center of the span and often at the ends as well. Some of the brick had loosened and ended up resting on the window head. A combination of horizontal and vertical movement had damaged some of the dovetail anchors between the brick veneer and the concrete columns. This movement had twisted the dovetail section of one anchor, almost completely disengaging it from the dovetail slot in the column. This occurred in an upper story near a corner where differential movement was greatest. The dovetail section of the anchor had been deformed about 25 mm [1"] vertically and 6.4 mm [1/4"] horizontally. Also a crack had developed at the narrow area where the dovetail section meets the corrugated section.

A water barrier of asphalt impregnated felts was adhered with mastic to the exterior of the CMU wall. It extended to provide cavity flashing at the shelf angle but did not extend beyond the toe of the angle. The interior face of the CMU backup wall was painted creating the interior finish. There was no insulation in the system and no other air or vapour barriers.

Case Study C: Anchored brick veneer with a reinforced, cast in place concrete backup wall, Performing Arts Hall constructed in 1974. **See Figure 3.**
Clad with brick veneer, this CIP concrete building is located on the west coast of the United States in a cool, wet region. Design temperatures range from -9.5 to +27 DC [15-80 DF],[2] design wind speed is 161 kph [100 mph],[3] and potential for seismic activity is relatively high (Uniform Building Code Zone 3).[4] The brick veneer clad both the vertical surfaces and the forty-five degree sloped surfaces just below the roof. Completed in 1974, the owner was investigating cracking and water entry problems by early 1976. The cladding was removed and construction of a new brick veneer was completed in 1994. The primary failure mechanisms were lack of expansion joints, inadequate connection of shelf angles, and poorly anchored veneer. Corrosion of veneer anchors had occurred from excessive water penetration through the brick clad inclined surfaces, cracks in the veneer, and parapet walls capped with a brick rowlock course.

The backup wall was integral with the 203-356 mm [8-14"], reinforced, CIP concrete structure. Hot-dipped, galvanized shelf angles were bolted to the concrete backup 6 m [20'] above the foundation and then at 3.66 m [12'] intervals. The anchor bolts were sometimes poorly installed, often inadequately spaced, usually with no shimming at gaps. As there were no horizontal expansion joints, the shelf angles served to partially constrain vertical movement of the brick veneer. This resulted in buckling loads that also contributed to some lateral movement. Furthermore almost no vertical expansion joints were installed and none that protected corners.

The brick veneer panels were tied to the concrete backup wall with 16 gage, corrugated or crimped, 25 mm [1"] mill galvanized, dovetail anchors. The dovetail slot was cast-in-place with anchors spaced 38-61 cm [15-24"] vertically and 71-96 cm [28-38"] horizontally. The slots had been deformed during placement of the concrete to the degree that many of the original anchors must have been ineffective as lateral play was often 9.5 mm [3/8"]. In investigating whether the slots could be reused it was found that in order to limit movement of the dovetail anchor in the lateral direction to 1.59 mm [1/16"] it would be necessary to use several different anchor configurations, some of which were not commercially available.

The cavity between the brick veneer and the backup wall averaged 25 mm [1"] in depth but ranged at the extremes from plus 75 mm [3"] to minus 50 mm [2"] (the brick was trimmed to half its depth and parged to the backup wall). There were frequent mortar droppings and bridges. Weepholes, when installed, were located a course above the shelf angle and flashing. PVC flashing, protecting the shelf angle, terminated before reaching the outer edge of the horizontal leg. The exterior of the concrete was coated with an asphaltic water barrier and there was no insulation in the system. The interior finishes consisted of painted gypsum board, brick veneer, and paint applied directly to the concrete backup wall.

COMPARISON OF BACKUP WALLS

What follows is an analysis and comparison of CMU, CIP concrete, and SS backup walls using the case studies as examples.

Lateral Loading

The backup wall must transfer wind and seismic loads from the veneer to the structural frame without causing excessive stress to the brick veneer panel. The more flexible steel stud backup should be designed to limit deflection thereby decreasing the width of cracks in the brick veneer and reducing potential water penetration. A deflection limit of L/720 for a SS backup wall, when considered alone at full lateral design load, is recommended by Canada Housing and Mortgage Corporation (CHMC).[6] The Brick Institute of America (BIA) recommends that the maximum deflection for a steel stud backup wall be L/600 to L/720.[7]

The stiffest backup wall is undoubtedly CIP concrete. However a stiff backup wall has no advantage unless the anchor tie has the ability to transfer the loads from the veneer to the backup. The dovetail anchor in a dovetail slot is commonly used with CIP concrete, and, as seen in case study C, this slot can be damaged during placement allowing excessive lateral movement. Construction tolerances create another problem with loads being transferred to CIP concrete. The allowable deviation from plumb is generally greater for concrete than brick masonry exacerbated by the fact that rarely will a CIP concrete backup wall (or concrete frame) be torn down if the tolerances are exceeded. When the deviation from plumb is 127 mm [5"], as occurred in case study C, the masons must somehow compensate which they did by shaving 50 mm [2"] off the brick and eliminating all anchors in some areas while in other areas expecting the anchors to bridge a 102 mm [4"] drainage cavity instead of the 25 mm [1"] cavity that was detailed.

The required stiffness is also easily acquired with a CMU backup wall. However, as noted in case study B, a poorly designed and/or constructed CMU backup can be as ineffective as a poorly designed and/or constructed SS backup. Although the initial problems of case study B were highlighted by the movement of the brick veneer, the veneer was also unstable because of minimal anchorage to the backup wall. But, even if this anchorage had existed, it would have had little effect, because the backup wall was not well connected to the structural frame. (Settlement of the building weight onto the backup walls in the lower stories might have allowed some of these 254 mm [10"] CMU walls to resist significant wind loads, but an analysis showed design wind loads could collapse many walls especially in the upper stories.) For a discussion of other CMU backup failures see "Old Problems and new Opportunities" by John A. Koski.[8]

The argument can be made that it is most difficult to design and construct a steel stud backup wall with the required stiffness. In addition, steel stud backup walls are often paired with inadequate anchor ties. The weak point of the anchor tie may be its connection to the steel stud. The safety factor can be increased by using an anchor that requires four fasteners instead of two or one. But this type of anchor is rarely used. In case study A the ability to resist lateral loading was also compromised by the use of fasteners with no corrosion protection and the lack of a backup plate on the anchor which left the gypsum sheathing, often wet, to transfer the lateral loads from the triangular tie. Although it was determined that at the time of our investigation, the SS backup wall was not yet contributing to the failure of this system, there was potential for future backup wall failures given the high lateral loading and continued corrosion of welds, fasteners, and the steel studs themselves. For more information on lateral loading of SS backup walls see "What is Wrong with Brick Masonry Veneer over Steel Studs" by Clayford T. Grimm.[9]

Environmental Controls

The backup wall is part of a system that provides environmental controls based on climate, building use, and location of the anchored brick veneer on the building. It can serve as, or be the base for, thermal and sound insulation; and water, air, and vapour barriers. There is no generic solution that works for all areas of Canada, the United States, or even regions having similar climates. The use of insulation and barriers is dictated by the outdoor relative humidity and temperature, external forces like wind and solar exposure as well as the design requirements for the relative humidity and temperature of the interior. The backup wall also supports or, in some cases, provides the interior finish surface.

Insulation is most economically added to a SS backup due to the cavity contained within the wall. However the steel studs act like a fin radiator conducting heat through the wall. Insulating the cells of concrete masonry has little effect as the area that can be insulated is usually minimal. A board insulation covering the entire backup wall and structural frame provides more consistent thermal resistance. Insulation with CIP concrete or CMU backup walls must be either added to the drainage cavity (or pressure equalized chamber) or to the interior. If placed in the drainage cavity, the stiffness of the anchor ties plus the size of the shelf angle must be increased to accommodate their increased unsupported length. Added to the interior, it reduces the available floor space thus increasing square footage costs of the building. Of the threes case studies only the SS backup wall had insulation added.

Water, air, and vapour barriers can be incorporated in all three systems. CIP concrete and CMU backup walls inherently retard some of the movement of water, water vapour, and air. The SS wall and its sheathing is much more vulnerable to moisture damage. If the water barrier and vapour barrier are omitted, as in case study A, moisture degradation of the gypsum sheathing is a problem, particularly with the presence of consolidated mortar droppings and bridges. The sheathing provides a surface for easy fastening of barriers but flexible materials such as "TYVEK" or polyethylene must be held rigid with an additional layer of gypsum sheathing or insulation board to ensure an air tight barrier. If the rainscreen principle is utilized, the air barrier must be complete, the veneer must have adequate openings to allow for equal pressurization of the cavity and exterior, and the cavity must be compartmentalized. For a discussion of pressure equalized rainscreen see: "Facts and Fictions of Rain-Screen Walls."[10]

Differential Movement

Brick veneer experiences both moisture and thermal growth, while concrete backup walls and frames shorten due to shrinkage, creep, and elastic deformation from loading. Because of differential movement, anchored brick veneer is designed as panels, separated by expansion joints, and tied to the backup so that the veneer can move independent of the backup wall in the vertical and horizontal direction but not in the lateral direction.

All three case studies experienced differential movement problems due to inadequate placement of expansion joints. This may have been an attempt of the designer to camouflage the panelized nature of brick veneer. They also had improperly spaced, installed, or designed anchor ties. The dovetail slots cast in concrete backup walls did not allow for horizontal movement and sometimes limited vertical movement as noted in case study B. Properly installed, two piece anchor ties that provide for horizontal and vertical movement can be fastened to concrete, concrete block, or steel stud backup walls. However the cautions noted under "Lateral Loads" concerning fastening anchors to steel studs should be considered. Corrosion resistance of anchor ties and fasteners should be determined based on anticipated water in the system. All of the case studies used galvanized anchors or anchor ties. However in the CMU and the CIP concrete backup walls the lack of anchor ties was a larger problem than insufficient corrosion protection.

Constructability

Numerous trades are involved in the construction of the brick veneered building envelope. In addition to masons, light gage metal workers, painters, and drywallers; these include installers of sealants and insulation; and installers of water, air, and vapour barriers. Electricians and mechanical contractors often route their systems through the backup wall. The work of these trades must be coordinated in both the design and the construction of the backup wall. Finally, the system must be constructable. What works on paper may not be buildable given the weather, scheduling problems, and the limitations of the local trades.

The backup walls in all three case studies had constructability problems. The deviation from plumb seen in the CIP concrete backup wall of case study C, produced a drainage cavity of minus 50 mm [2"] to plus 75 mm [3"]. The installation of the cast-in-place dovetail slot limited the vertical movement of the anchor and allowed excessive lateral movement in both case study B and C. These problems are common, and the cladding system is rarely redesigned to compensate. Usually the masons on the site simply make the best of it. They lay the brick within their tolerances and use the dovetail slot as installed by others.

The consolidation of trades in the construction of brick veneer with a CMU backup wall can be an advantage as the change of trades occurs when the connection of the backup wall to the structural frame is made. With the CIP concrete backup, using a dove tail anchor/slot system, the change of trades occurs during the connection of the veneer to the backup wall. The masons are responsible for inserting the anchor in a slot installed by the concrete subcontractor. If a problem develops often neither party is interested in taking responsibility.

Constructability of the steel stud backup is of principal concern. Given a well designed and detailed wall, with the required stiffness, many on-site installation procedures can cause problems. The welding of steel studs requires a great deal of skill, care, and inspection. Case study A exhibited a number of faulty welds where the wall was welded to structural steel, and in some areas the steel stud flanges were partially burned away. There were also faulty welds in the steel stud wall. BIA recommends against field welding of steel studs.[11] It might also be inferred from this technical note that shop welding of 18 gage studs is not advised.[12]

The design of ribbon windows alternating with bands of brick, as used in case study A, is problematic. It requires a light backup wall that can be cantilevered in two directions from the floor structure resulting in the shelf angle being welded directly to the studs. (It is recommended by BIA that the shelf angle NOT be welded directly to steel studs.[13]) The building discussed in case study A also had a curved wall, created by cutting the top and bottom stud tracks every 39 cm [16"] to form the radius. The cut tracks were not fastened back together after the curve was completed. None of this was detailed in the drawings. The trend towards curved walls coupled with the design flexibility of the steel studs may lead to serious problems. A designer will indicate a curved backup wall but the design and detailing is left to the steel stud subcontractor. Rarely are shop drawings of the system required.

The steel stud wall does have the advantage of more easily accommodating electrical, plumbing and other mechanical lines. The same accommodations can be made with a CIP concrete and CMU walls, but the layout must be designed prior to construction, and changes are difficult.

Economics
While it may be possible to design a functioning envelope system many projects do not have the budget necessary for the system's proper implementation. Too little may be budgeted for quality workmanship and adequate construction contingencies. Low professional fees may not allow for careful design, detailing, and inspection of the system. And often too much of the fee is used during the conceptual design stages to later provide for good detailing or adequate inspection.

It is obvious why a SS backup wall is selected over a CMU or a CIP concrete wall and it can be expressed in a single word - economics. The steel stud backup wall is less costly for two reasons: the materials cost less, and the relative weight reduces the size and consequently the cost of the structural frame. Since time is money the cost is further reduced because the installation is quick and not weather dependent; changes in electrical, plumbing, and mechanical connections are more easily implemented; and the building can be "closed in" more quickly meaning the project is completed sooner. SS backup may be the only solution for a project with a tight schedule.

CONCLUSIONS

From the study of these three buildings coupled with investigations of similar buildings and an understanding of general building economics, the following arguments can be posed:

1. As illustrated with case studies B and C, the longevity of anchored brick veneer may be more dependent on the design, detailing, and construction of the entire building envelope system than on the selection of the backup wall. The selection of a concrete or concrete masonry backup is not necessarily a panacea for building envelope problems.

2. A SS backup has potentially more associated risks than a CIP concrete or CMU backup. In addition, because the SS backup is usually chosen because of its initial low cost, there may be a tendency to also reduce costs in other critical areas

exacerbating the problems.

3. The search for less expensive building envelope systems will continue. Brick veneer is often chosen based on cost. It is less expensive than precast, most metal, glass, or stone cladding systems. Only E.I.F.S. is a less expensive cladding. The economics of construction in Canada and the United States will likely dictate that steel studs will continue to be frequently selected as the backup for brick veneer, keeping the system as economical as possible.

The problem then becomes how does one assure that the backup wall, as well as the entire building envelope system, is well designed, detailed, and constructed within the constraints of the budget.[14]

To assure proper functioning of the backup wall, the design of all components of the building enclosure system need to be detailed and coordinated. A good primer is *Exterior Wall Construction in High-Rise Buildings: Brick Veneer on Concrete Masonry or Steel Stud Wall Systems*, published by Canada Mortgage and Housing Corporation.[15] It is not enough to specify components and their installation merely by referring to recommended standards and practices of trade associations and manufacturers. The recommendations are likely to be adequate. But without details particular to the project, anomalies such as the curved steel stud backup wall discussed in case study A are designed in the field and generally not by structural engineers. In addition the implementation of the recommended practices is left to the trades who often do not have or take the time to consult the referenced standards and who should not be responsible for coordinating the design of their work with other trades. A good example is that of case study A where the powder-driven fasteners, installed by the window installer, punctured the PVC flashing protecting the angle.

In addition to detailing the system, the architect and other consultant professionals should take responsibility for the design by requiring shop drawings and by being involved in the inspection of the system. Inspection and responsibility are two words that make architects and engineers very nervous. Their attorneys and insurers often advise them to avoid responsibility by placing the liability on others. Inspection of construction is evaded by using euphemisms such as "observation of construction." But, whatever the terminology, the designer of a building enclosure system has the responsibility to assure that both the design and the implementation of the design are adequate within the limits of his or her control.

An owner may want control of part of the process in an attempt to reduce either the construction cost or the professional fees. It would be in the designers best interest to refuse such a project than to be faced with a failed system several years later. If the project is to be tendered, the backup wall will often be constructed by the subcontractor who submitted the lowest bid. In this situation even greater care should be taken in the design and inspection of the backup wall and other components of the envelope system. Often a good rule of thumb for the owner is to spend the money saved by accepting a low bid on additional testing, inspection, and a larger contingency.

There also needs to be an honest assessment of initial cost in view of durability. The owner needs to be presented with the facts - they are trading lower installation costs for higher deferred maintenance costs as well as potential liability should the veneer fail. Given that veneer accounts for 90% or more of the brick used in Canada[16] and that steel stud backup walls are not likely to disappear, it is time we start viewing the backup wall as a component of the building envelope system. A system which must be carefully designed, detailed, specified, and constructed for the performance time line called durability.

ACKNOWLEDGMENTS:

The author wishes to acknowledge Russell Heliker of Brock Associates for his work on the three case studies and thank him for his assistance in reviewing this paper.

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1. The three case studies were investigated by the masonry consulting firm, Brock Associates. The author was the principle investigator of the brick veneer with SS backup wall. Russell Heliker, general manager and investigator for Brock Associates, was the principle investigator of the brick veneer with CMU backup wall, and the brick veneer with CIP concrete backup wall. For more complete information see technical reports available from the author.

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14. The following is an interesting discussion on the economics of brick veneer as part of a complete system: Kudder, R.J., "Deliver Masonry as a Cladding System," *Magazine of Masonry Construction*, The Aberdeen Group, Illinois, August 1994, pp.385-367.

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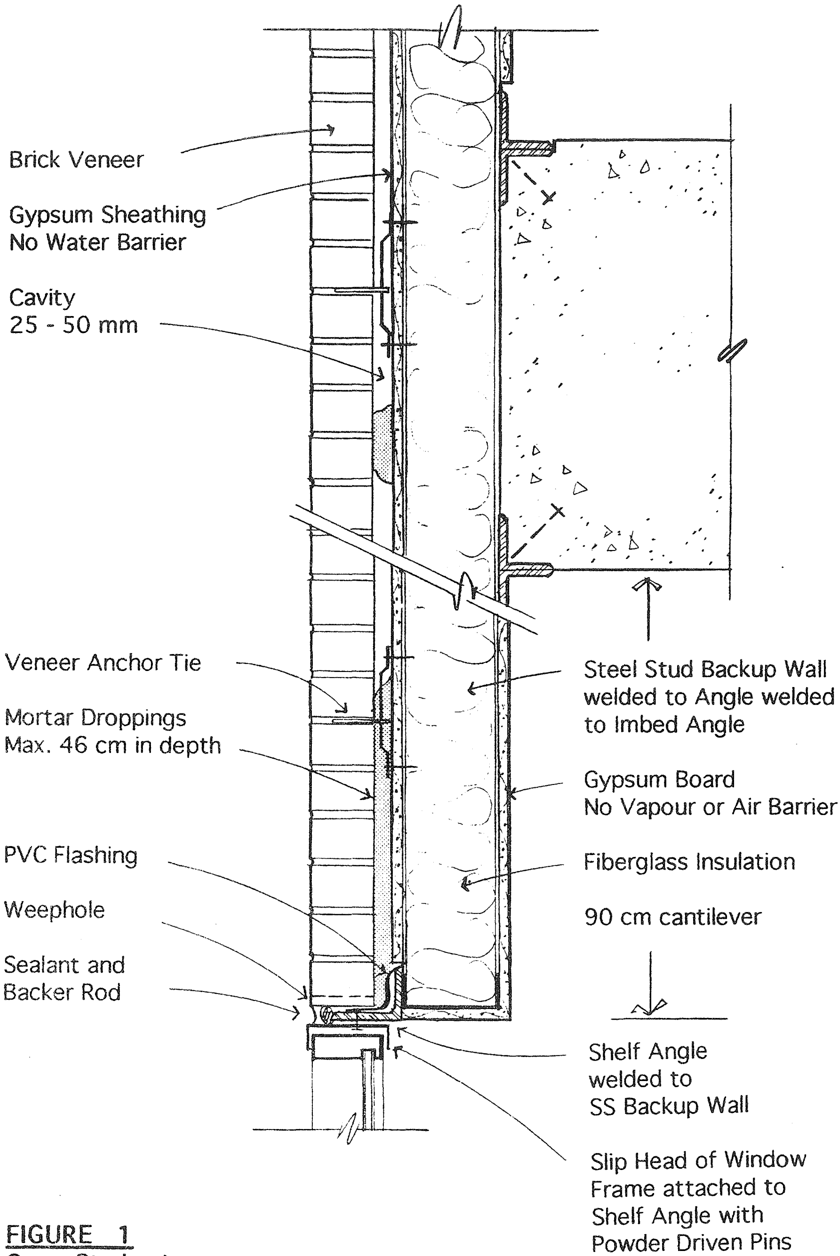

FIGURE 1
Case Study A
Brick Veneer with Steel Stud Backup Wall

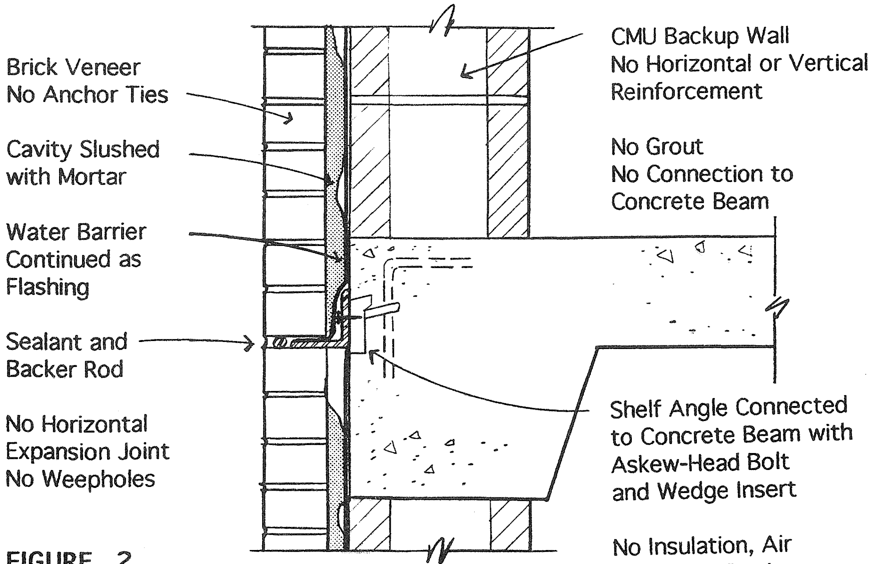

FIGURE 2
Case Study B
Brick Veneer with Concrete Masonry Backup Wall

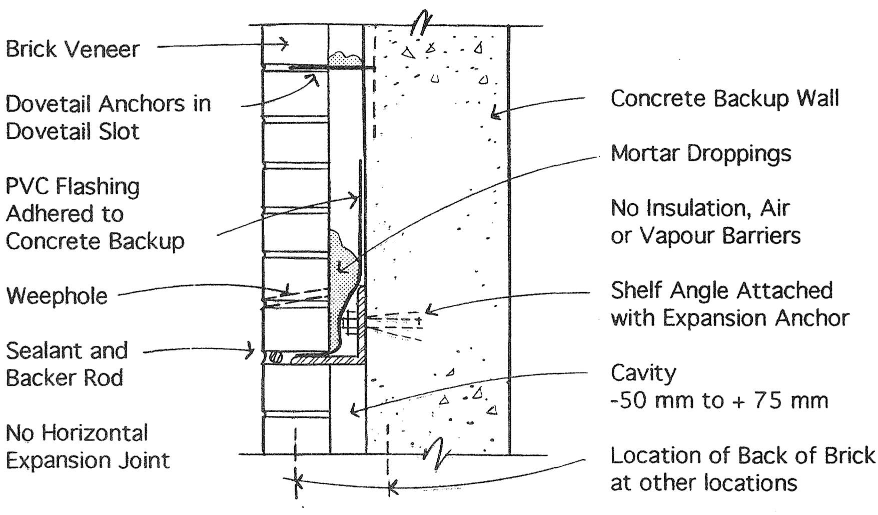

FIGURE 3
Case Study B
Brick Veneer with Concrete Backup Wall