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Systematic Integration of Details

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Abstract

How can a wall assembly be built without water penetration problems?

Throughout North America there have been increasing reports of water intrusion into recently constructed buildings. The problems have resulted in a provincial government inquiry and numerous research projects. The Canadian Standards Association's Guideline on Durability in Buildings (CSA S478-95) has been introduced into the National Building Code as a recommendation for good practice.

The construction process is complex, requiring cooperation among many partners. Establishing a quality control program early in the design process will contribute to the successful construction of the building envelope. The success of a project begins with the design of the details and with ensuring that all partners comprehend their intention. The provision of isometric or 3-D illustrations with notes is a step in that direction. The use of a third party building envelope specialist is recommended. Testing of a mock-up is also recommended where complex details require evaluation of installation methods and materials. Project and detail specific training of all parties involved, from craftsman to supervisor, will ensure that the necessary knowledge for success is provided.

A large hotel project is reviewed where some of the above steps were utilized with mixed results. Time and financial pressures are always present but the long term cost of failure considerably outweighs the savings obtained by unevaluated cost cutting during construction.

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Introduction

Recipe for Disaster

Take one owner with capital budget; separate operating budget and ignore.

Add one architect and heat until steamed.

Expose three or more tenders, exchange parts, and trim extraneous portions.

Select thinnest and discard remainder.

Remove architect, save essence.

Assemble subtrades, compare and trim extraneous portions. Select thinnest.

Store subtrades in dark.

Collect shop drawings in separate bowls; do not premix.

Add subtrades one at a time, do not allow time for mixing, turn up heat.

Add just enough caulking to make it all stick together.

Turn over onto owner. Serve wet.

There are many variations to this recipe. Anyone experienced in the construction industry has heard of one or, unhappily, been involved in one. The resulting problem which has moved front and centre in recent years is that of rain water penetrating the building envelope, leading to premature deterioration and loss of durability of materials within the building envelope.

The reports of water intrusion damage are so widespread that various organizations are now involved in studying the problem. Most notably, the National Research Council Canada (NRCC) has instituted the Moisture in Exterior Wall Systems (MEWS) Consortium to evaluate water penetration into wall assemblies. Other organizations such as the American Society for Testing and Materials (ASTM E06.55.04 committee) and the American Society of Heating, Air Conditioning and Refrigeration Engineers (ASHRAE SPC160-P committee) have established task groups to develop standards relating to the prevention of water intrusion damage. Other

organizations such as Oak Ridge National Laboratories in Tennessee and the British Columbia Building Envelope Review Committee are also involved in related research.

Why did water penetration into buildings suddenly become such a big problem? The BC government appointed a commission of inquiry headed by former Premier Dave Barrett to ask that question. The commission report should be required reading for anyone in the construction industry. Among the report's important observations on 'What Has Gone Wrong' was the following:

"In addition to economic pressures, climatic conditions, and a systemic failure of the building process, building science also played a role in bringing about this crisis of confidence. The factors related to ... building science, include: ...

"a loss of collective memory, and lack of conventional wisdom, among inspectors, architects, engineers, developers, and contractors regarding the requirements for effective building". [1]

This appears to be the common element of water intrusion problems. For whatever reason, there appears to be a 'loss of collective memory, and a lack of conventional wisdom' on how to build effectively. Rain is not a new phenomenon and buildings have not always leaked, at least not to the current extent.

This paper emphasises the preparation effective details and their systematic development and integration into the building envelope. The approach outlined below focuses on window installation. It is not unique to windows but, as a very large percentage of water intrusion problems appear to be related to window performance or installation, it is a logical place to start.

The systematic approach

The systematic approach comes from working backwards from success. For example, review a window installation that doesn't leak. Why doesn't it leak? Because it was installed in such a way that water penetrating the exterior plane was directed to the exterior. How was that accomplished? The installers co-operated with adjacent trades and installed the components as designed and tested. How did they know how to do it? The contractors were specifically trained in the proper installation sequence based on a successfully tested mock-up. Why did they test a mock-up? The specifications called for a mock-up to be tested. And so the process goes, back to the original design concepts. Step by step, each party assumes responsibility for the quality of their work.

"A fundamental principle of quality assurance is that all persons accept responsibility for the standard of their own work." [2]

The Canadian Standards Association's Guideline on Durability in Buildings (CSA S478-95) describes a thorough rationale for quality control in construction and a process for

achieving it. The guideline emphasizes that a commitment to quality control must be introduced with the design concept and carried through to completion of construction and, ultimately, into ongoing building maintenance. The guideline has been included in Part 5, Environmental Separation, of the National Building Code of Canada (NBCC) subject to review in the next code cycle.

The following model of a systematic approach to integrating details complements CSA S478-95. As noted above, window installation will be used in the examples. The model demonstrates the four essential steps of this approach:

1. Design details with installation sequence in mind. The concept or intent of the detail should be stated as part of the detail.
2. Include a third-party quality control firm in the process.
3. Build a mock-up of critical details and test using selected materials and subtrades.
4. Provide job-specific, step-by-step training for subtrades and inspectors; training to be conducted by the third-party quality control firm in conjunction with product manufacturers.

Design of details

“Detailing should be provided using clear, concise, and complete drawings and specifications ...” [3]

The successful integration of details does not begin with the creation of details. It begins with defining the concept behind the details (e.g., face-sealed, source drained or flashed, drain screen, etc.). When the design concept is understood and clearly stated in details and specifications, it becomes easier to maintain consistency among all details in the cladding assembly.

“ Components and techniques which are critical or difficult to install correctly should be clearly detailed and explained in design documents.” [4]

Unfortunately, designers are restricted in their ability to provide a complete set of details because they often don't know which products will be used until the tender process is complete. An effective alternative to a complete set of details is a set of preliminary details with the design concept and performance expectations clearly stated on the details. The details should contain notes stating, for example:

- intention to create a 'source-drained' assembly
- rough opening must be protected
- penetrating water to be directed to a flashing
- flashing to divert water directly to the exterior
- installation of the sealant must allow water to drain to the exterior

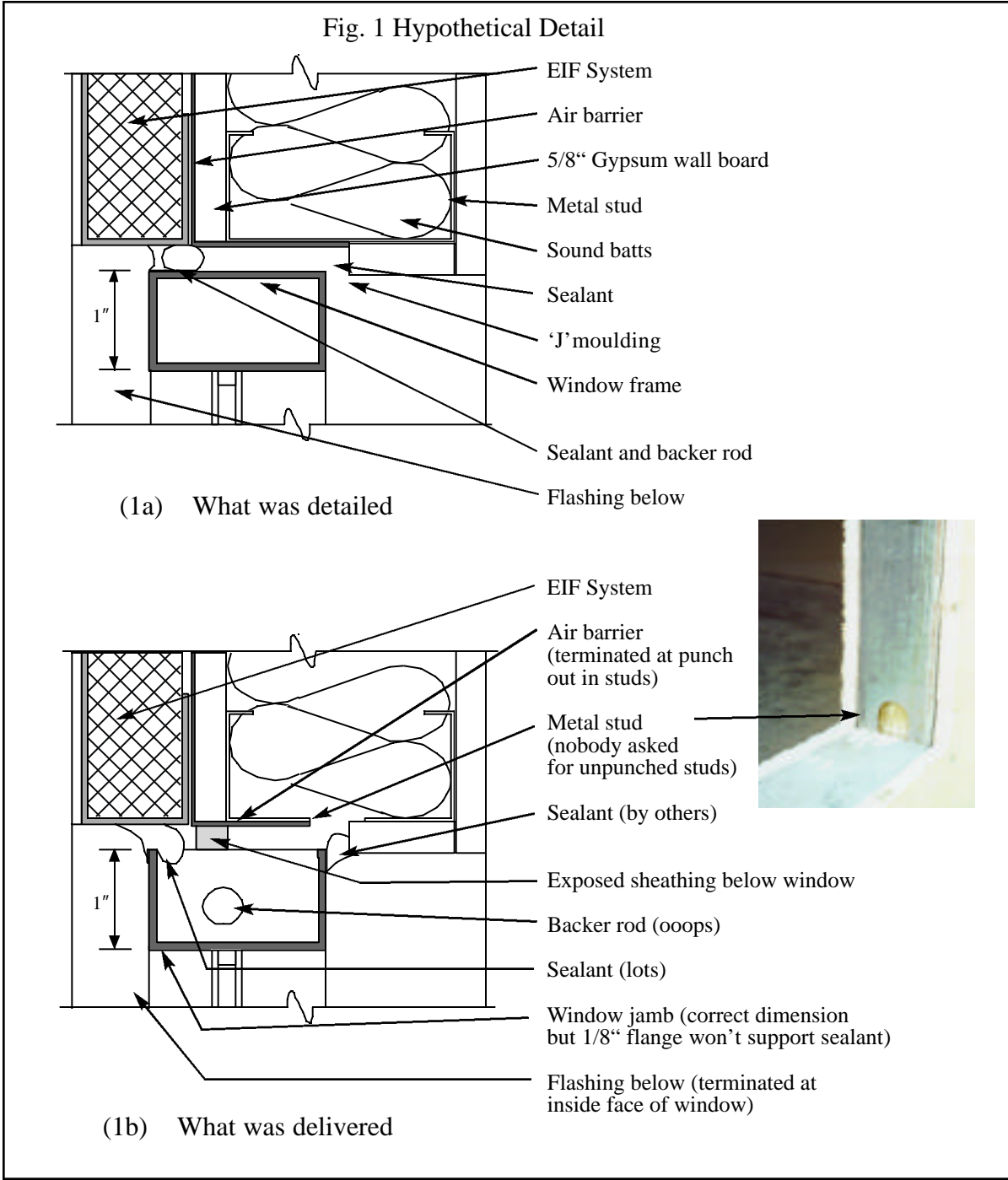
Given notes like these on a set of details, subcontractors bidding a project will have the basis for the design available to them. It is inevitable that alternatives and substitutions will be proposed in any tender process. With an understanding of the design concept, it should be easier to evaluate the proposed alternatives, both before and after their submittal.

What can happen when a designer does not clearly state performance expectations on a drawing? Fig.1a shows a hypothetical example of a detail provided without notes. Fig. 1b illustrates how various subcontractors made substitutions in the absence of clear information. To a casual observer inspecting the installation after construction, the installation would appear to match the design as given. In reality the substitutions, however well intended, could lead to water intrusion.

The box window frame shown in Fig.1a is a favourite for a designer who has no idea which window manufacturer will be successful in the bid. Though in every other way an abstract, the box does enable the designer to indicate the exact location and dimensions for whatever window is chosen. The 'box' as drawn, however, conveys the illusion that a perfect supporting surface will be provided for backer rod and sealant.

Three other points should be noted about Fig. 1a. The designer has provided for a peel-and-stick air barrier to be installed over the rough opening, so there was no need to consider punch-outs in the stud. 'Flashing below' is noted but it is unclear whether it is below the entire window or not. The selected cladding is EIFS; however, there is no indication for sequence of installation, method of draining water which penetrates the exterior plane, or how the materials are to be integrated at a change in plane, e.g., the jamb-sill interface.

Fig. 1b shows what was installed. The EIFS installer changed from a peel-and-stick membrane to a trowel-applied air barrier that would be compatible with the EIFS adhesive. Unfortunately, this type of air barrier by itself will not bridge the punch-outs in the stud. Punch-outs, as shown in the inserted photo, can end up anywhere. The window frames used are of the required dimension and positioned exactly as detailed. Unfortunately, these particular window extrusions have 1/8" flanges, too narrow to support sealant or backer rod. When installed, the backer rod drops into the frame. The outer seal becomes a poorly configured seal of indeterminate dimensions. In this hypothetical example, the sill section (not illustrated) did not show the position of the flashing clearly. As the method of draining water intrusion through the window was not made clear, the windows were supplied on the assumption that water would be drained behind the cladding. The flashing has therefore been installed under the front flange of the window, leaving the interior sill unprotected and the sill sheathing exposed. When the sealant fails because of its poor configuration, there will be uncontrolled air and water leakage into the stud cavity.



Preparation of Details

Critical details, typically those depicting an integration of components and a change in plane, should be drawn in isometric or 3-D format. Prepare the detail step by step, showing the progressive integration of the components using the sequence of installation that will be

employed in the field. If it is not possible to draw the detail on paper following this method, a designer cannot expect the installer to build it in the field.

As noted above, the designer should be specific about the intentions of the design. It is necessary, for example, to go beyond naming the components to:

- Point out that the window is expected to sit on a flashing.
- State that the membrane around the window is intended to drain into the pan flashing. Make it clear that the pan flashing is to drain outbound of the cladding.
- Tell the subtrades bidding the job that they may have to work in stages with other subtrades in order to complete the detail correctly.

Whatever information the designer thinks will be critical for the successful bidder to become the

Fig. 2 EIFS Commercial Window Head

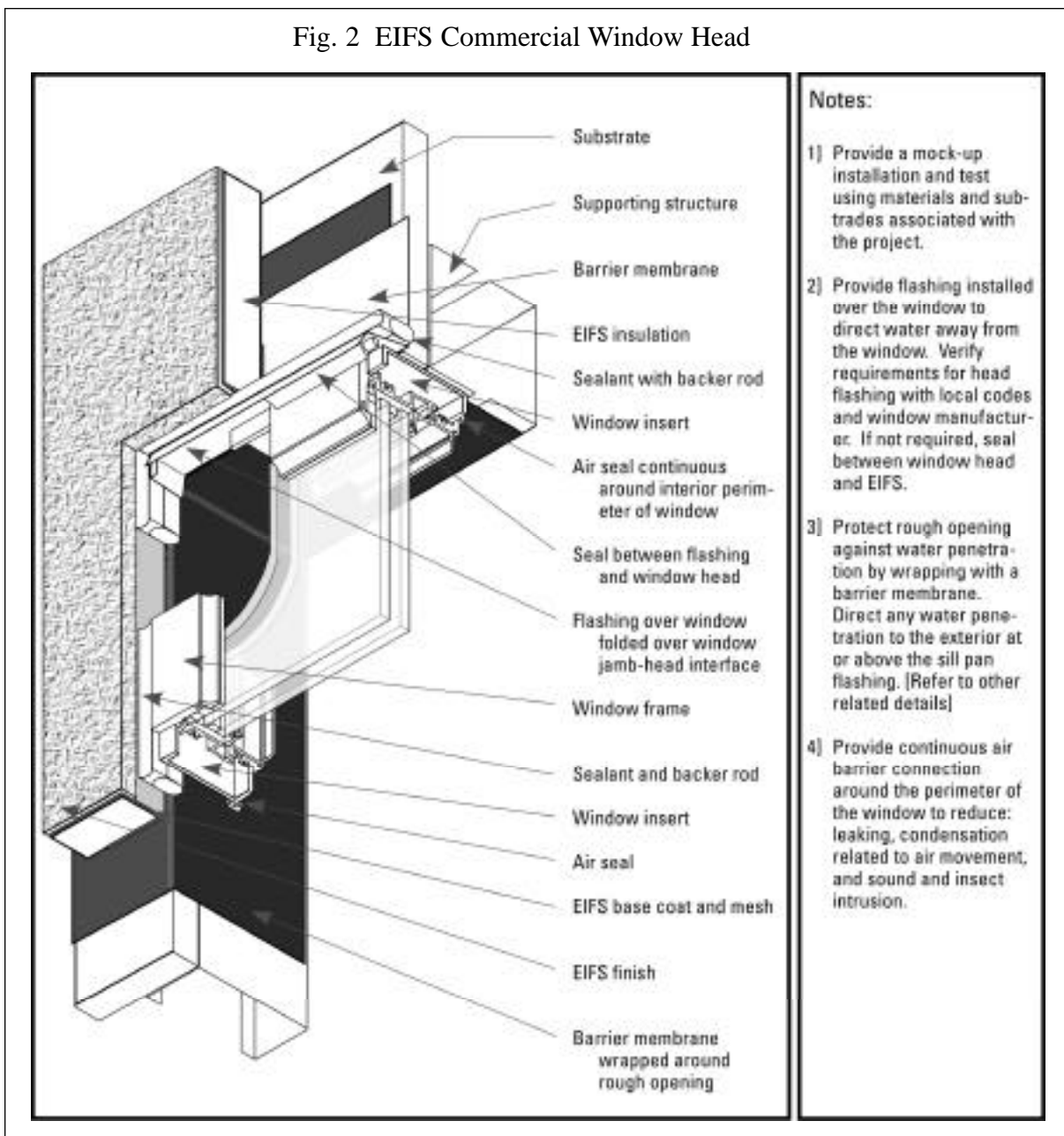
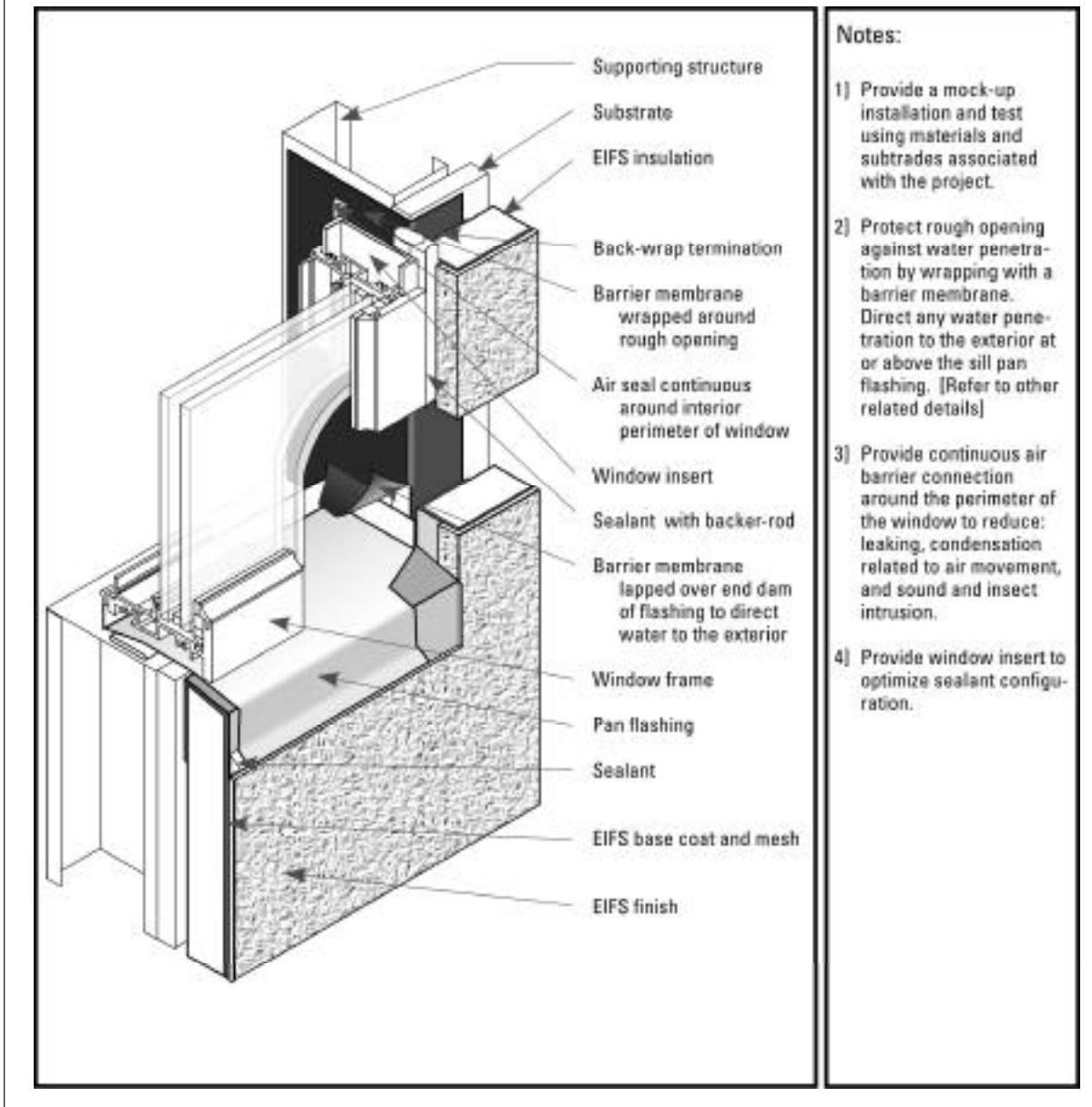


Fig. 3 EIFS Commerical Window Jamb

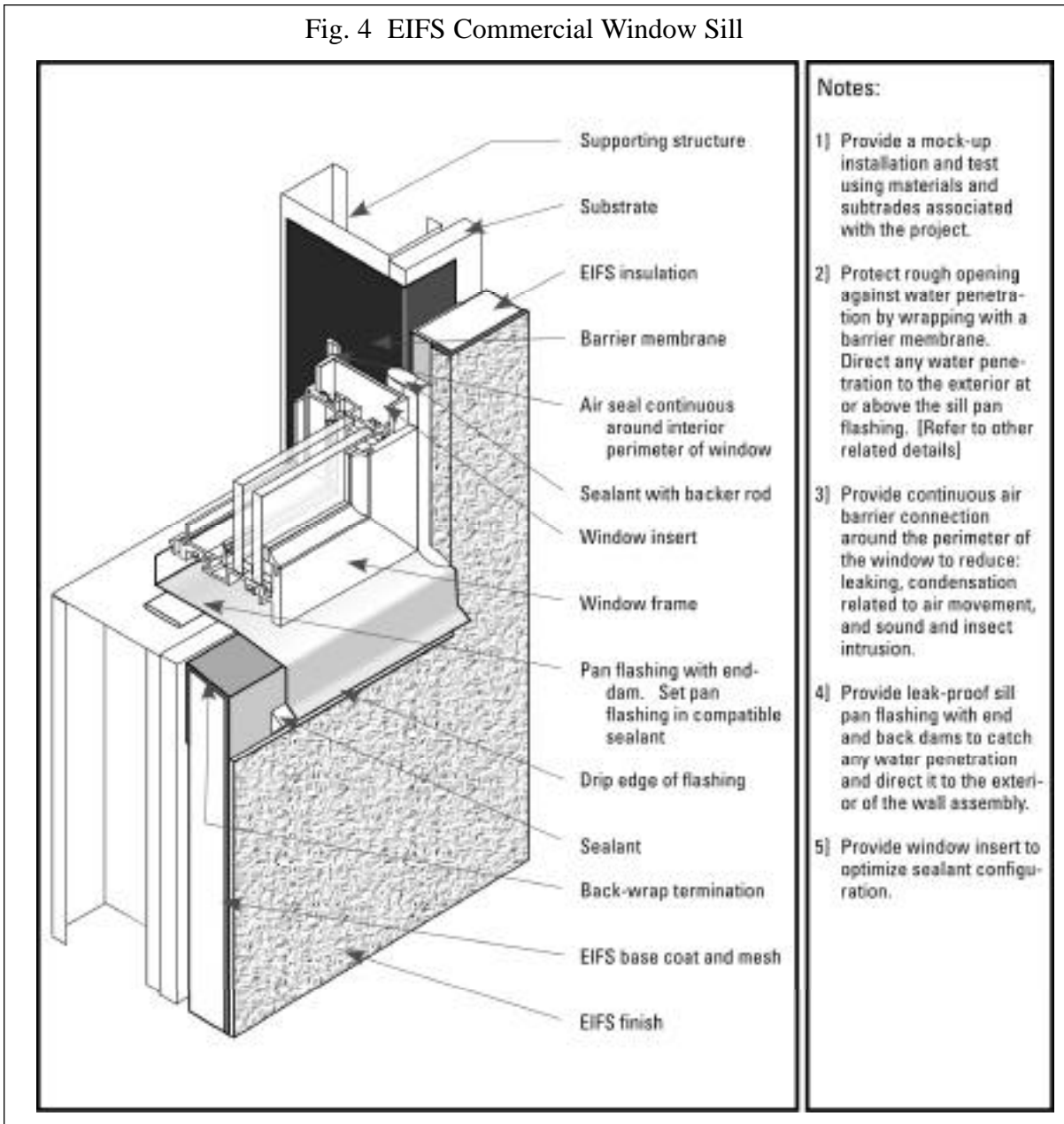


successful installer should be printed on the detail.

Figs. 2, 3, and 4 illustrate how isometric details can give more information than simple sections. The format shows how materials meet at changes of plane. The notes illustrate the expectations of the designer. For example, the detail includes notes directing that the rough opening be protected and that water be directed to the exterior at or above the sill pan flashing. It also references associated details.

The details shown in Figs. 3 and 4 include a note to “Provide window insert to optimize sealant configuration”. In other words, the detail calls attention to the potential problem of inadequate bearing surface for backer rod and sealant in some window designs. These details are illustrations from one manufacturer’s literature for the detailing of EIFS [5]. Clearly they go

Fig. 4 EIFS Commercial Window Sill



beyond the installation requirements for EIFS to include other components that will have to be installed correctly if the whole wall assembly is to perform as desired. It is obvious from the details that water which penetrates the window installation is to be drained at the sill and not behind the cladding.

Third-Party Quality Assurance

Third-party inspection used to be the traditional role of the architectural firm. When a contract was formalized between the owner and the general contractor, the architectural role automatically changed to that of referee (otherwise known as site architect or Clerk of the Works) representing the owner's interests. Today, the building envelope is becoming so

complicated that owner and architect are turning to specialist firms to coordinate the transition from design to completed functioning envelope. In this, the architect should recognize the special knowledge of the building envelope specialists and how they can provide assistance in developing a successful project

In response to Vancouver's water intrusion crisis, city officials recently changed their building by-law to include the requirement for a certified Building Envelope Professional to be involved in all projects. Training and certification were to be handled through the professional associations of the architects and engineers. Although a legal issue has caused the suspension of the formal program, the training remains. Quality assurance programs similar to Vancouver's will become more common as the CSA S478-95 Guideline on Durability becomes a recommendation for good practice in the National Building Code.

The third party has many responsibilities throughout the project. The scope of these responsibilities must be negotiated with the owner but in terms of the process being described here, that scope should include:

- reviewing the details prior to tender
- implementing changes to design drawings as necessary.
- reviewing the bidder's understanding of the technical requirements of the job
- directing and supervising mock-up construction and testing
- preparing the training manual
- verifying the accuracy of the installation of the components.

Full scale mock-up and test

When a project is large enough to justify the expense, the designer should specify a full-scale mock-up of the window installation to be built and tested prior to the start of construction. Any details that may be critical to the performance of the envelope, such as vents and joints, should be included. The cost of a basic set up and test may start at approximately \$5,000. If the cost of mock-up testing appears to be excessive for the project, compare it to the cost of repairs if the initial installation were to be unsuccessful. An acceptable alternative may be to review detail testing conducted by a material manufacturer [6] and accept those designs. Sometimes the mock-up may be incorporated into the finished construction, which could help to mitigate the expense. Field testing to the ASTM E1105-90 standard [7] may be used to evaluate samples in situ and to provide verification during construction if necessary.

The subtrades under contract for the project should build the mock-up. This requires considerable advance notice and co-ordination because some components, such as windows, may be custom built for the project. Building one window for a mock-up rarely fits the scheduling of the manufacturer, but waiting for the completed production run may be counterproductive. The window may fail and require modification.

All manufacturers whose products will be used should be actively involved in the design and execution of the mock-up test. Questions of material compatibility should be resolved at this point, along with delivery schedules, material storage requirements, climatic restrictions or any other factor that could affect the successful completion of construction. For example, if there are temperature restrictions for a component of the installation, it should be taken into consideration at this early stage; e.g., EIFS application will require temporary protection and heat if the temperature is likely to fall below 5°C/40°F during construction.

Detailed records—drawings, photographs and possibly video—of the construction of the mock-up should be kept by the third party. Not only will such records be necessary when developing the installation guide, but they may also prove crucial for an analysis of what went wrong if the initial test fails. It should be an accepted fact that mock-up tests tend to fail the first time. Considerable concern and stress for all involved will be avoided if the owner understands this in advance. It is far better to discover what doesn't work while testing a ground-level mock-up than after all windows have been installed on the actual building.

All parties should understand that the mock-up must perform satisfactorily prior to the start of work. The details and construction methods successfully utilized in the mock-up will be duplicated on the building and some verification testing may be requested.

Step-by-step Training Details

The critical component of the quality control process is training.

Once the mock-up has been successfully tested, step-by-step details should be prepared by, or under the supervision of, the third party so that each subtrade knows the correct installation sequence. Photos taken during the mock-up phase are helpful and a video is better.

Typically, only a small crew is involved in building the mock-up. In order to ensure the success of the test and to minimize costs, it is natural for a contractor to use his best personnel. However, there can be no guarantee that these people will be assigned to this particular project. In addition, it is inevitable that during the construction process personnel will change. New people, whether on the installation or supervision side of the process, will have to be trained on the proper sequence and installation methods. The third party should establish a procedure to ensure that any new person involved in the construction of a critical detail has been trained.

How the best of intentions can miss the mark

In a recently completed hotel project located in an area subject to violent rain storms, portions of the above program were implemented. During the early development stage, the EIFS manufacturer and a window manufacturer worked with the project designer in developing a plan for integration of the window into the EIFS-clad wall. After tender, a different window manufacturer provided the successful bid. Their shop drawings included the two details noted in

Figs. 5 and 6. The cladding manufacturer involved with the original design concept reviewed the shop drawings and noted some potential problems:

- The sill and the jamb were protected with an “adhesive waterproof membrane”. At the jamb the membrane was behind the EIFS but at the sill it was over the EIFS. The transition was a mystery.

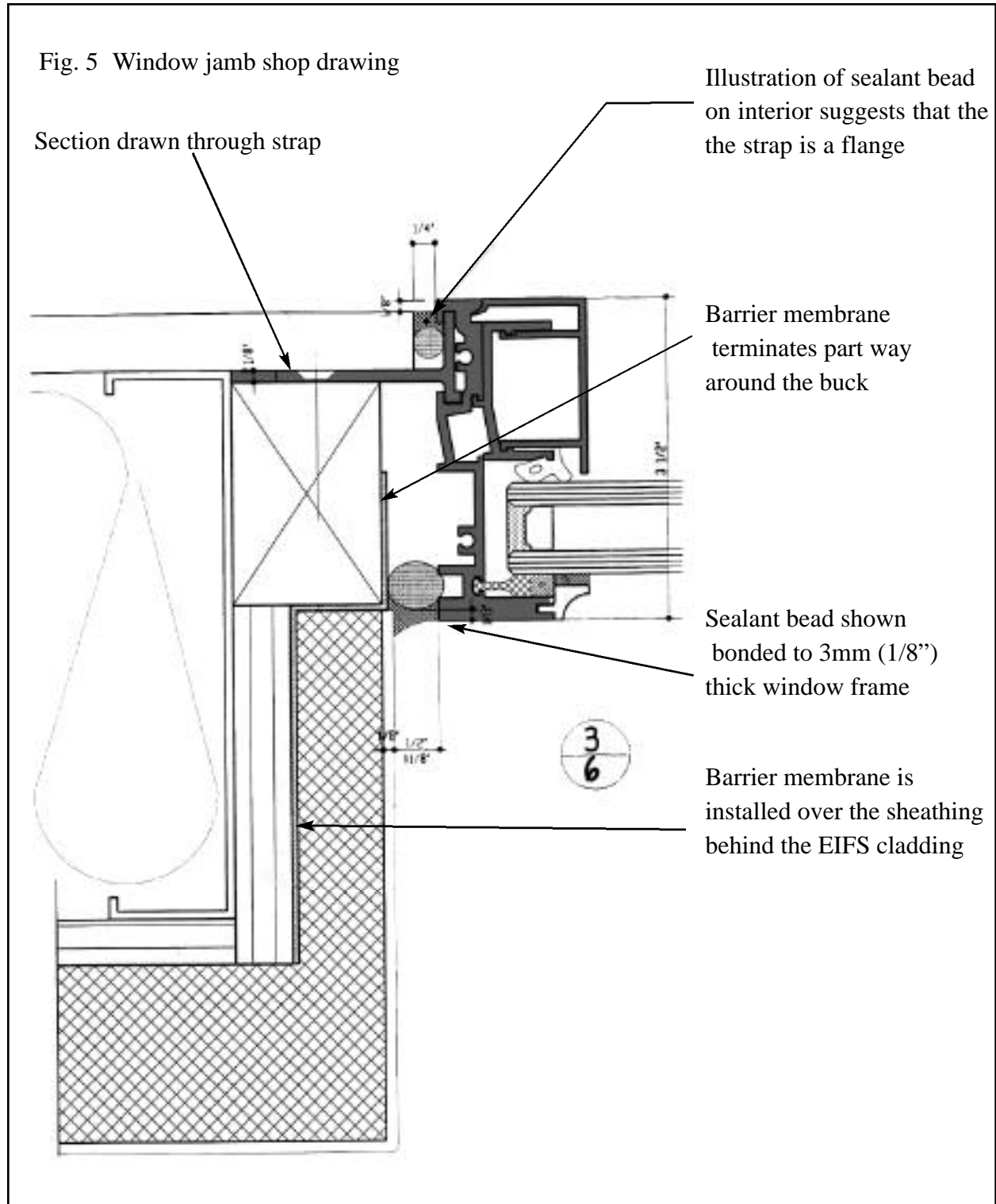
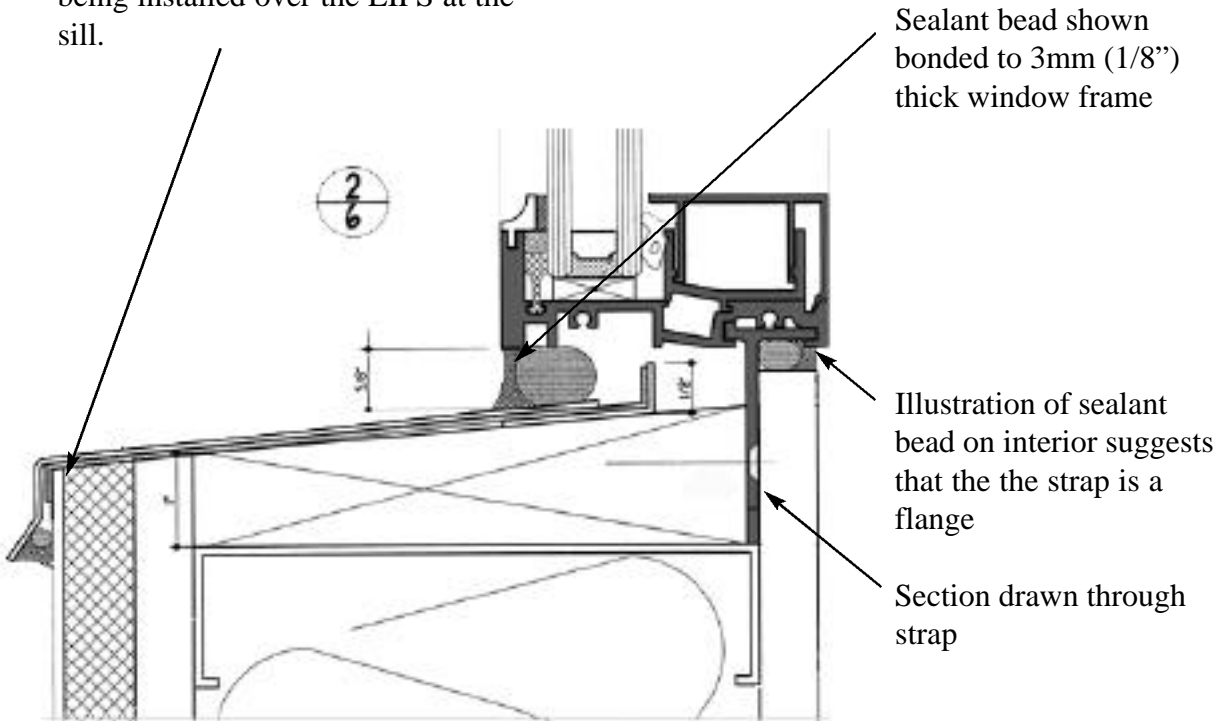


Fig. 6 Window sill shop drawing

Barrier membrane is illustrated as being installed over the EIFS at the sill.



Sealant bead shown bonded to 3mm (1/8") thick window frame

Illustration of sealant bead on interior suggests that the the strap is a flange

Section drawn through strap

- The pan flashing as illustrated did not protect the whole sill area.
- Details showed an interior perimeter flange with backer rod and sealant air seal between the flange and the drywall. This was not a problem in and of itself but when the mock-up window arrived for testing the ‘flanges’ turned out to be straps. The shop drawing sections were taken through the straps. There was no provision for a complete perimeter air seal and, in all probability, it was never envisioned.

The mock-up was built and tested for water penetration. It failed. Subsequent tests, isolating different components in the mock-up, determined that it was the windows that leaked. At this point a few other factors compounded the problem: reportedly, the 800+ windows had already been manufactured in South America and were on a boat in transit, and the project was on an extremely tight schedule as the hotel’s opening nights had been booked. The problem was resolved by the window manufacturer, who wrote a letter guaranteeing that the windows would not leak.

Fig. 7 Installation sequence for waterproofing window rough opening

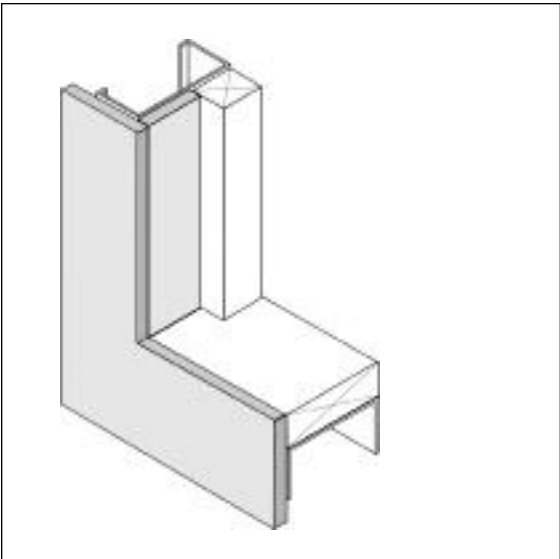


Fig. 7a Rough opening with wood buck in place. The sheathing is returned into the jamb and head (not shown) to accommodate trowel-applied waterproofing.

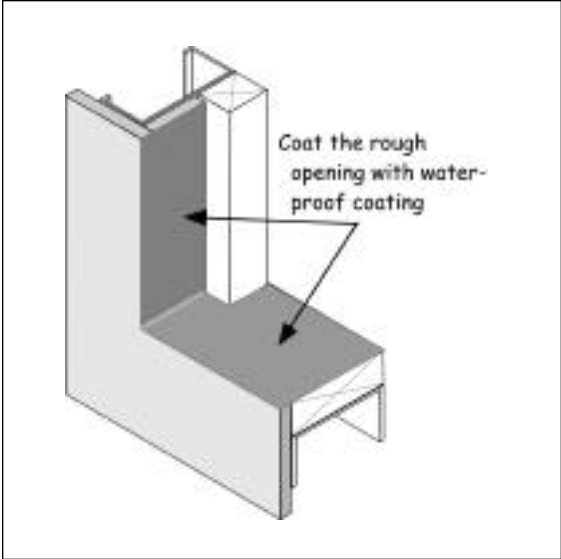


Fig. 7b The rough opening is coated with a trowel-applied, waterproof coating.

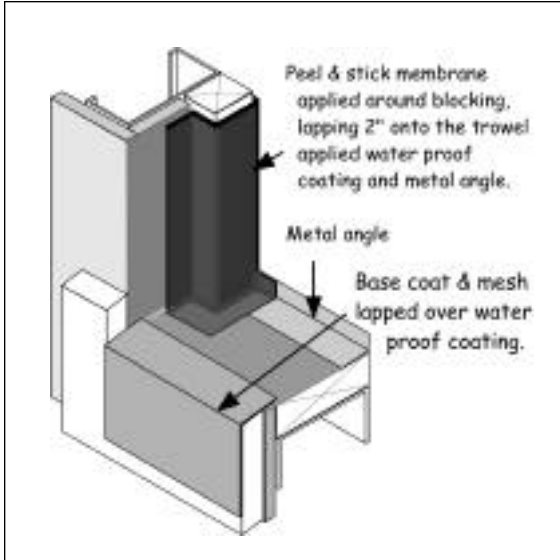


Fig. 7c Insulation, 'L' cut for the opening, is installed at the sill. Base coat and mesh are applied lapping onto the sill. A metal angle, acting as the back dam for the flashing, is installed in line with the back of the rough opening. A peel-and-stick membrane is wrapped around the jamb buck lapping onto the angle and trowel-applied waterproofing.

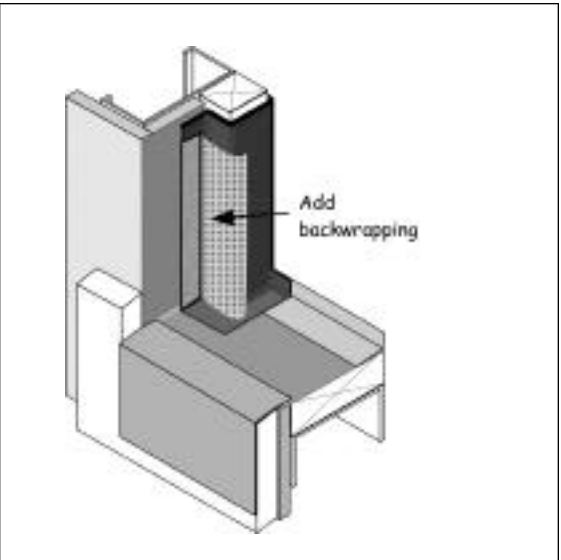


Fig. 7d The backwrapping is started for the insulation to be installed on the jamb. The back-wrapping should be started on the compatible waterproof coating and lap onto the peel-and-stick a maximum of 50mm.

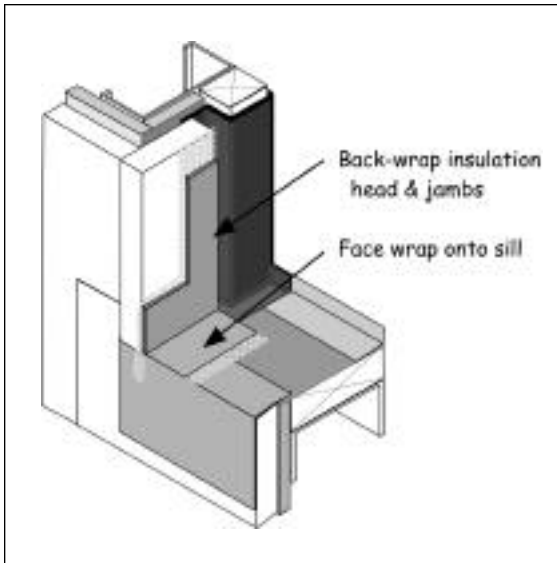


Fig. 7e The rest of the insulation is installed around the window opening and on the face of the wall. The back-wrapping is completed and the base coat is lapped onto the sill.

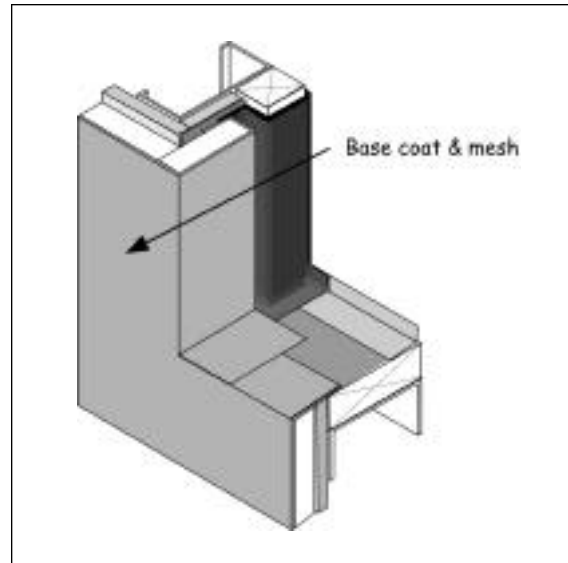


Fig. 7f The balance of the base coat and mesh is installed over the face of the wall.

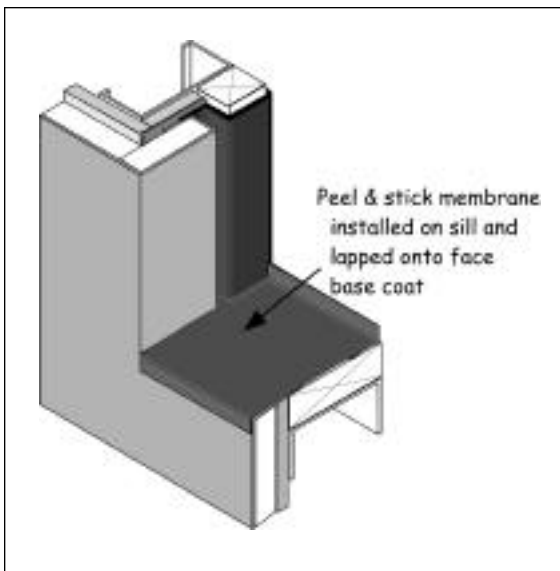


Fig. 7g A peel-and-stick membrane is installed over the the sill, turning up onto the metal angle. At this point the membrane has been installed behind the EIFS on the jamb and over the EIFS on the sill.

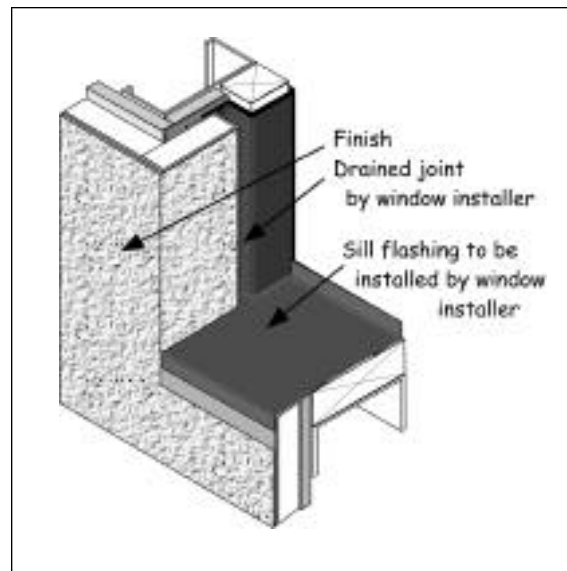


Fig. 7h The EIFS installation is complete. The window installer will set a metal sill flashing into parallel ribbons of sealant running from the back dam to the face to allow drainage. The window is installed over the pan flashing.

In order to overcome possible water penetration problems, the cladding manufacturer prepared a series of step-by-step details (Figs. 7a to 7h), based on the mock-up. These were to assist the EIFS installers to waterproof the window rough opening so water would drain to the exterior of the cladding. This would protect the wall cavity from the potential nonperformance of the windows.

The project proceeded on its very tight schedule. During a site visit near the end of the project, it was discovered that the installers preparing the openings, their supervisors and the general contractor's site superintendent had all been replaced during the course of construction. The new personnel did not know of the step-by-step details that had been prepared but were sure that they had been followed. A close inspection of the installation confirmed that this was likely correct but that the sealant contractor had tightly sealed the drainage exits under all the windows. Water penetration through the window, inbound of the sill flashing, will now be trapped under the sill. As the rough opening is protected, water will accumulate in the sill up to the point of the leak. If the air seal is flawed on the interior and the accumulating water reaches that point, it will spill into the interior of the building. This presumes that there is an air seal, the lack of which would result in immediate penetration of water into the interior of the building. A missing air seal could also result in increased leakage. Assuming that there is no route for the water to flow out of the cavity, it will dry by evaporation through the most vapour-permeable portion of the wall, the EIFS.

A written notice of the incorrect installation of the sealant to the general contractor did not cause the anticipated concern because, fortunately, the window manufacturer had written the guarantee that the windows would not leak.

The hotel opened on schedule.

Conclusions

Time and money dominate the construction process. Above all else, completion on time and on budget drives the agenda. Compromises are inevitably made during the construction process to resolve problems and meet deadlines. 'Value engineering', which has become an accepted phrase for cutting costs, can be misused to the detriment of the project. To be consistent with the program outlined in this paper, and with the CSA standard on durability, it will have to be recognized that cost flexibility comes with an evaluation process. It will not be possible to make changes or to 'value engineer' without demonstrating that the performance of the envelope or long-term operation costs will not be compromised.

One of the handicaps to building for long-term performance has been that the capital cost of construction has become isolated from the long-term operating costs. The introduction of CSA S478-95 Guideline for Durability into the National Building Code as recommended best practice

should make operational costs a more important element in the equation for design and construction.

Accurate and comprehensive detailing, as described in this paper, will make the construction requirements clearer to those bidding the job. When cost estimates improve, better reflecting the design intentions, 'value engineering' and compromising for the sake of cost will become less necessary. The presence of third-party quality control personnel will be less of a threat when the job has been priced properly.

The decision to follow a quality control program needs to be made and implemented at the earliest stages of a project. It must be clear during all phases that each party is responsible for their portion of the work *and* for coordinating with others involved in the project. The inclusion of third-party quality control will direct the program through in a coordinated and successful manner. The Building Envelope Professional complements the architect on site by assuming the responsibility for the building envelope details. The architect may, indeed, fill that role.

The testing of a mock-up, while not appropriate for all projects, provides the basis for proceeding with confidence that the design can work as intended. It will also, at the outset, resolve sequencing and coordination problems which might otherwise cause delays during construction.

Training related to the specific details logically follows a mock-up testing program. The creation of a job-specific training manual and training records will provide tangible assurance that the craftsmen on the job know the job. Advance knowledge of sequence, personnel and equipment requirements, and material compatibility should speed construction.

There are many who will find these recommendations costly and onerous, with the potential to delay progress on the job. Architects may object to the loss of their traditional role in site supervision. Owners may not want to pay the additional costs related to third-party quality control. Contractors and subcontractors will not want to jeopardize their competitiveness by including the costs for mock-up construction and training time. Accepting the responsibility of cooperation may frighten those who have tried to maintain legal protection by focusing exclusively on their portion of the contract.

It is, on the other hand, easy to weigh the costs of participating in a quality control program against the cost of water penetration problems and their resolution. Given the original alternative, why not write a recipe for success?

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