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RCI Foundation • 1500 Sunday Drive, Suite 204 • Raleigh, NC 27607-5041 • Phone: 800-828-1902

ACHIEVING SUSTAINABLE SOLUTIONS FOR THE BUILDING ENVELOPE

Thomas William Hutchinson, AIA, CSI, FRCI, RRC
Principal
Hutchinson Design Group, Ltd.
Barrington, IL

Abstract

Seventy-five percent of all commercial construction completed prior to 1990 gave little or no consideration for long-term performance, energy performance, or environmental impact. Design professionals have opportunities to improve on existing building construction in the form of roof replacement, masonry restoration, window replacement, and curtain wall renovation. The potential solutions are multifaceted. This paper focuses on how the design professional can manage this opportunity to achieve sustainable design solutions. Guidelines (parameters) for achieving this sustainable improvement are provided, together with examples.

Abstract

Seventy-five percent of all commercial construction completed prior to 1990 gave little or no consideration for long-term performance, energy performance, or environmental impact. Design professionals have opportunities to improve on existing building construction in the form of roof replacement, masonry restoration, window replacement, and curtain wall renovation. The potential solutions are multifaceted. This paper focuses on how the design professional can manage this opportunity to achieve sustainable design solutions. Guidelines (parameters) for achieving this sustainable improvement are provided, together with examples.

Introduction

Before any new concept implementation, the ultimate end goal should be clearly and definitively stated and understood through the definition of terms. Make no mistake: sustainability is about long-term performance. Together with the concept that building envelope area systems (roof, walls, curtain walls, panel, masonry, combinations, etc.) are systems that are only as good as their weakest component, the idea of sustainability must be holistic in approach, involving the entire building envelope system. The inclusion of green parameters, which are representative of only one segment of sustainable practice in designing and rehabilitation, without the other key hallmarks will not necessarily result in the realization of long-term performance. Thus, the keys to sustainability are not independent, but must act with synergism to result in a component assembly achieving long-term performance, while satisfying the eco demands as envisioned by the owner and designer's interpretation of "true sustainability."

Moisture Intrusion, the Devil's Advocate

In this paper terms are defined as follows. The "building envelope" is defined as the roof and the walls, their materials, and their interfaces that establish the structure. Before beginning discussion about the building envelope and practices to achieve sustainability (i.e., long-term performance) and to prevent moisture intrusion, first to be understood are those water infiltration effects which vary by building and material type.

1. Dimensional change: Some materials shrink with time; others expand. However, all materials will have some expansion and contraction over the life of the material. These changes repeat as temperatures and the climate change.
2. Mold and mildew: These growths are manifestations of moisture infiltration; they can close down even the finest of buildings. In today's marketplace they are an ever growing possibility and a concern within the building design profession and the construction industry.
3. Premature deterioration: Moisture infiltration causes materials to fail to reach their full potential. Thus it compromises not only the building, but also its sustainability.
4. Efflorescence: This occurs when salts leach out of building components as those components dry out after continuous wetting cycles.
5. Corrosion: When in continuous contact with water and air, steel corrodes, expanding to many times its original size. This results in the movement and deformation of adjacent materials such as masonry, wall panels, and wood framing.
6. Disintegration of force materials: Some products, such as wood, deteriorate greatly under continued wetting cycles. In these conditions the wood disintegrates, causing movement of neighboring components. Other disintegrating situations, such as the previously indicated expansion of rusting and corroding steel, settlement due to erosion, and movement due to wind loading, can all dislodge material components. This results in cracks and crevices in the façades and the building envelope. Thus, water infiltration increases, which results in increased deterioration.

7. Material disfigurement: Conditions such as paint blistering, surface staining, and delamination, change the physical appearance of the material.
8. Incompatible materials: Moisture can act as a facilitator of corrosion between differing incompatible materials.

Recognizing effects of air and water infiltration is not enough. Architects, contractors, and other individuals involved in the building industry also must understand the infiltration mechanisms to be able to design and construct with the purpose of preventing air and moisture infiltration. Moisture intrusion is the element most responsible for premature building material/system failure, and results in the failure to attain long-term performance. Air infiltration is most often responsible for energy inefficiencies, energy loss, condensation concerns, and environmental issues.

Three conditions are necessary for moisture infiltration to occur: point of entry, presence of water, and force to move water through the space, typically air or negative interior building pressures. Experience has shown that typical conditions of concern are:

- joints between field-constructed components and factory-manufactured items, such as masonry construction and prefabricated windows;
- conditions of excessive deflection;
- locations of differential settlement;
- locations of a material experiencing warp;
- joints between materials having different coefficients of expansion;
- materials changing dimensions due to excessive gain or loss of moisture;
- shrinkage; and
- joint movement.

Five forces work to move moisture through the building.

- gravity;
- capillary action;
- kinetic energy;
- hydrostatic pressure; and
- differential air movement.

Control of these forces is vital to successful waterproofing of any structure.

Push Toward Sustainability a Concern?

The essence of sustainability is long-term building performance*,* which allows continued use of a building for its intended function. In this case, materials and system interaction are compatible. Additionally, a building also provides security and safety. Recent developments in the United States under the auspices of the Leadership in Energy and Environmental Design (LEED) were introduced with good intentions, high hopes, and altruistic value with regard to the environment. While this goodwill has affected the landscape of construction and design in the United States and is moving toward worldwide practice, it is not without concern. Currently, there is no tie to building or material performance with regard to the prescribed LEED credits toward building award (though it does appear that LEED 2009 is attempting to move in that direction). The LEED award or credit system often gives more emphasis on product selection than system or component performance. Many high-ranking LEED buildings are moisture intrusion nightmares. In any new program or product, details need to be worked out as implementation occurs. It is hoped the stewards of LEED programs, as well as others throughout the world, realize the importance of long-term building performance and the role of sustainability in that goal, and that they listen to and ask advice from consultants, architects, and contractors whose daily livelihoods focus on the building envelope and are impacted by their construction.

The continuous introduction of new building and construction materials and systems often results in latent concerns in the design and contracting communities, frequently after installation makes remediation difficult and expensive. Many products are brought to the forefront untested or unproven on the building types on which they are purported to work. The moisture-intrusion catastrophe that occurred in Vancouver in the late 1990s is a prime example. The concern there mostly involved the use of exterior insulation finishing systems (EIFS). Another example is the current exterior wall system installation utilizing steel studs being promoted in the United States. Because studs are located amid the insulation and the fact that steel conducts temperature greater than wood, dew-point condensation is occurring within the wall system. Mold growth ensues. Designer, owner, and contractor must tread lightly when incorporating new materials into building envelope systems. Another condition is the combination of materials of differing compositions, expansion and contraction coefficients, and compatibilities that are being incorporated into façades. These materials include metal, glass, stone, and masonry, each with different coefficients of expansion, rates of absorption, and resistance to deterioration. Use of materials with different physical characteristics complicates matters more today than in buildings of the past.

Building complexity and innovation is also growing. “Star architectural design” features often push the limits of traditional building form, challenging contractors to assemble components that are presented in architectural renderings on paper, yet in practice are exceedingly difficult to build/achieve in the field. By some measure, the ability of the architect to design and draft exotic building envelope features has exceeded our ability to construct them. These architects are often known for their metal and/or glass-skinned buildings, but should also be known for designing buildings that have been moisture infiltration disasters. In some cases, moisture infiltration resulted in complete deterioration that is so extensive that the demolition of the structure is required. The question might be asked if pushing barriers results in good architects or wealthy attorneys? In today’s society when a building leaks, the building owner looks for the responsible person. This results in legal action. Architects of the past, such as Frank Lloyd Wright who intimated that if a building didn’t leak, the design was not pushed far enough, would most likely be in continuous legal battles if he were alive today.

Many contract documents being submitted to the construction industry today reflect a departure from the age-old definition of architect as master builder. Many contract documents are basically incomplete or marginal documents, produced by inexperienced draftsmen. They include the inappropriate use of computer-aided design (CAD); where details from one project are brought over to another project. One set of details may or may not be appropriate to a given project. This practice is causing great harm to the building industry. Also, poorly executed construction drawings that rely on manufacturers’ standard drawings are one of the prime reasons modern buildings leak excessively. In reference to performance, minimal specifications are given with the intention of maximizing performance. Often the designer of record has no knowledge of why qualifications are listed when, in fact, those qualifications are based on testing standards. In such a situation, the designer of record would be unqualified to review submittals from manufacturers, since manufacturers are driven by the marketplace and cost. It is this author’s firm belief that the designer of record should not only design, detail, and specify exactly what is desired, but also should not leave those decisions up to individuals whose only concern is a single part of or perhaps an incomplete item of construction.

Somewhere in the construction process, owners must be educated to realize the importance of quality contract documents and quality construction, their cost, and the value of achieving them. Poor installation is not only the result of unknowledgeable installers; it is also due to the fact that construction costs are often driven so low that compromises must be made. A prime example of such a compromise is the use of sealants. Sealants are used extensively in modern buildings to prevent air and moisture infiltration at the junctures of dissimilar materials. Since construction sites are often dirty, dusty, and filled with airborne contaminants, and surfaces are often unclean or unfit to receive sealants, it is not always easy to achieve a proper bond. Use of a primer at least guarantees that a surface has been cleaned once before installation.

In addition, the ineffective use of or misplacement of bond breakers and foam rods has often led to many premature sealant failures.

Rarely will you see a window manufacturer accept the responsibility for a leak, with all blame quickly assigned to everything around the window. This is another example of a disconnect in the industry. Singular component manufacturers and industry watchdogs lobby heavily to limit their potential liability through smoke screens of acceptance testing that overshadow the realities when their products are installed and fail. "We had the assembly tested and it passed." The only thing passing now is water and the buyer or owner is less than pleased. The building envelope industry would do well to develop and implement design and performance standards that recognize the dynamic nature of our built environment.

Achieving a Sustainable Building Envelope

Determine a Durability Target. If long-term performance is the essence of sustainability, then defining the building's lifespan and building component service life is a necessary step in achieving sustainable structures. The City of Milwaukee, Department of Public Work initiated such a program under the leadership of Venu Gupta, Facilities Manager, whereby all the building systems in new construction and in the renovation of existing facilities must be designed to achieve a 30-year service life. Their life-cycle analysis and life-cycle assessments have shown quick returns on investment and payback on additional dollars spent.

Review and coordination of this concept with the owner are required. Code-mandated service life minimums are just that: minimums. Those wanting to achieve sustainability will desire service lives well beyond the code.

Building Trade Coordination. Many of today's buildings have complex façades with obtuse geometric forms and a variety of cladding materials, all installed by differing contractors. The coordination of these disciplines and trades on a project must be implemented in design and carried through the preparation of drawings, specifications, and construction.

The design team needs to ascertain each façade materials' characteristics, detailing, and interface needs, and to design appropriate interfaces, paying homage to how buildings are constructed, the sequencing of installation, and predictable performance characteristics based on real world experience. The preparation of correct details and coordination with the specifications, inform all parties that coordination of shop drawings with other trades at interfaces are crucial factors in obtaining long-term performance. The details must define which trade is providing which component.

The design team needs to understand the importance of careful review of shop drawings and view this as the last chance to see that all the contractors understand the building façade construction. While the general contractor construction manager is ultimately responsible for the coordination of construction, the architect can assist in procuring the desired result. Shop drawings should reflect the installing contractor's work, but also that of interfacing trades. Shop drawings with insufficient or uncoordinated details should be rejected and returned. Special attention should be paid to how moisture moves once behind a cladding material and how it will be "weeped" out.

On-site full size mockups constructed by all the trades involved in the façade should be undertaken. The mockup should represent the final installed construction so aesthetic concerns as well as coordination and constructability issues can be reviewed and resolved. Water testing the mockup is prudent to verify the appropriateness of interfaces, various flashings and cladding systems, and to confirm that water drains out, once "in."

Understanding the Forces of Nature

Understanding the forces of nature is another key component of designing building envelope systems. Such forces include, but are not limited to sun, heat, cold, humidity, wind, moisture, and ice. These natural forces push the building materials and envelope systems toward failure. From the date of installation, these forces work day and night, 24 hours a day, seven days a week, and 52 weeks a year to try to defeat and compromise the building envelope system.

While many of nature's forces will deteriorate materials or compromise the building envelope's systems, it is water moisture that has the greatest deleterious long-term effect on the building envelope. Water, whether in the form of solid, liquid, or gas, has been affecting building envelope performance since mankind moved out of caves into arboreal huts. Water attack on building envelope systems comes in solid, liquid, or gas form, individually or in concert with each other. For example, frozen water expands, not only pushing against materials, but when infiltrating materials, such as roofing and sheet metal, it expands and pushes materials apart. This allows for more water infiltration, more freezing, etc., resulting in ever greater expansion. Being cyclical, the effects are ever increasing.

Obviously, liquid water in the form of rainwater, groundwater, or melting snow can penetrate the building envelope, entering through defects in the envelope system as well as through appliances that penetrate that system. The method of travel through any given deficiency would be either gravity, diffusion through porous materials, or capillary action. Consideration needs also to be given to wind-driven rain. Designers who have never seen rainwater driven vertically up a window wall system, up-slope on metal roof systems or in through steep roof systems composed of multiple shedders such as shingle, clay, or slate tile, do not fully understand the forces of nature. This infiltration often acts as a solvent as it passes through materials, picking up chemicals that might be more deleterious to materials with which it will come in contact further down its drainage path.

Most designers, owners, and contractors have seen efflorescence on masonry exteriors. This efflorescence is the result of moisture intrusion and the desalinization of that moisture. Such salts then collect on the building exterior as the moisture evaporates.

When moisture in the form of vapor under pressure (both positive and negative) comes in contact with the smallest and slightest of openings, penetration occurs. This vapor penetrates into a building system until it comes to a climatic condition where the dew point is reached. Condensation then occurs. Often slow and continuous; over time vapor moisture intrusion through building envelope systems and the resultant condensation have devastating results. When hidden behind material surfaces and therefore unknown, complete deterioration can occur.

Key Elements to Prevent Envelope Failures

Based on the author's 20 years of experience in design, detailing, and observation of new construction, analysis of existing construction, and research, failure patterns have begun to appear. Acknowledging and compensating for these patterns are key to preventing failure and promoting long-term building envelope performance. All members of the project building team should be aware of the processes that a building construction undergoes, starting with concept, through implementation, and ending with occupancy. A number of phases need to be incorporated first and reviewed by the several parties having input. Understanding these phases and how they interact assists in the coordination and understanding of how building projects work.

First is the architect/engineer (A/E) selection. At this point in the project, the owner has in his mind only an idea of what he wants the building to be. Selection of the A/E could be critical to the success of the building. As with all trades and fields, the quality of architectural firms varies with regard to design and implementation of design in the contract document process. A full review of qualifications in both areas is needed in the critical initial phase of the project. Second, if site selection and procurement are not completed before the A/E is selected, it is done soon after with the A/E's input. As discussed later in this paper, selection of an appropriate site for its building type and material usage will be imperative to the success of the building. For example, locating a building in a wind zone or an area where high or microburst winds might occur and using materials that are susceptible to wind uplift is not only conducive to short-term performance, but also borders on negligence. Third, the A/E meets with the owner to define building parameters and goals. Meeting with users, the A/E needs to find out what the building users' needs are. How is the building to function? What are the owner's goals, both user-wise and performance-wise, with regard to many of the operating systems, including engineering, HVAC, and electrical. How do they all relate to achieve the end goal? Thus, the building program as defined and all the interrelationships of interior spaces and exterior access points are coordinated. Fourth, the architect or designer sets forth a preliminary design; often preparing one or more schemes that will perhaps satisfy the user's needs. Many of these will differ in architectural type, distinction, and design.

Once a design is selected, it moves into design development, the fifth step. The design is refined. Detail conditions are considered. At this point materials begin to be selected and implemented into the design. Critical selection of some products can mean the difference between failure and long-term performance. Compatibility of materials and their interrelationships should be investigated. The designer should be coordinating this with the project manager and the person who will be detailing the building. Following acceptance of design development by the owner, the project moves into the sixth phase, contract documentation. At this point design intentions are translated into a communication tool that the contractor can use to build the project, (i.e., blueprints, specifications, etc). This is where many buildings begin their failure process. Failure to communicate the goal and intention of the project, properly to contractors involved in the project as well as solving the design detailing requirement, has put many an architect into a courtroom. At this point, it is the responsibility, or obligation of the architect to take into consideration the design, materials, and integration of the materials into the various building systems, as well as material compatibility and appropriateness. These parts need to be integrated into a whole where all parts work together. Failure to do this will predictably result in marginal or diminished performance. In the seventh phase, a project is bid. At this point, the quality of the contract documents will determine the quality of the bid. Scope documents that leave contractors with too many choices or too many unanswered questions are detrimental to the construction process.

In the eighth phase, after a contractor has been accepted and the contract awarded, the construction administration process begins. In this phase, all the months, perhaps years, of work come to fruition. Now it is in the hands of the builder to fulfill the owner's dreams or leave them half empty. Prudent owners realize the importance of having on-site construction observation to assure compliance with contract documents, to answer questions as they arise in the field, to resolve potential conflicts with regard to design and implementation, and to keep the owner informed of the construction process. At this stage, shop drawing review by architects should not be passed off to younger staff, but should be implemented and reviewed by architects or project managers who are more knowledgeable about the products they are reviewing. For example, a junior architect/draftsman should not review shop drawings for very complex window–wall systems or roofing systems that require extensive coordination with other systems, such as structural, masonry, and plumbing. The ninth phase includes final construction completion, the commissioning of systems, and issuing of warranties. In this phase, the project is commissioned, which is the testing of systems, making certain they perform to the specifications.

Post-construction maintenance is also a very important and required aspect of building performance. A building should be considered a living element and as such, it requires continuous maintenance. Usually, maintenance occurs on the interior on a fairly regular basis. It is the exterior façades and sub-grade elements that are not given regular attention. These elements are allowed to perform untouched for years on end. On the other hand, ongoing preventive maintenance is one of the best dollar values an owner can invest in after the building is in place.

Errors or misjudgments at any of the above phases can compromise building integrity, resulting in built-in envelope failures that are very costly to repair once construction is complete.

Respect for and Understanding Designing for the Effective Climatic Conditions

Indigenous designers realize the importance of giving consideration to climatic conditions and implementing design techniques that respect local conditions. Picture if you will a hot, arid climate region. A building in such a region would benefit from thick massive walls and shade-producing elements. Large overhangs work in areas of extreme wetness; steep roofs work in areas of heavy snowfall. However, as the world has become smaller and smaller and designers are no longer indigenous to the areas in which they design, the art of respecting the climate is often lost. Roofs blow offs and façade failures have increased. Window failures due to wind pressure as well as air leakage have increased. Occurrences such as these have become more commonplace as more and more designers refuse to respect climate effects. Design and detailing must respect and be implemented according to local climatic conditions for a building to succeed. Furthermore, understanding the local qualifications of local contractors is also critical to long-term performance. This author was once involved in designing a roof system for an international pharmaceutical company on a southern island of Japan and was considering the use of a fully adhered roof membrane, when it was communicated that the local trades were not very familiar with this type of roof system, but were quite familiar with metal roofing. A change in the roof system to respect the local trade expertise resulted in a roof system of high quality (and one that resisted the frequent baths of volcanic ash better than a membrane system would have).

Also, the physical characteristics of materials need to be given consideration. For instance, how will a wall perform in a certain climate 24 hours a day, 7 days a week? Sun, negative and positive wind pressure, and humidity are just a few of the elements that need to be given consideration for all buildings exposed to a given environment. Listed below are a few examples of conditions where lack of consideration of climatic conditions could lead to concealed condensation, the result of relative humidity and humidity differential, and further material deterioration and mold growth.

- Vapor and air barrier type and location. Incorrect location may lead to moisture entrapment. For example, salt-infused fog along coastal areas can lead to corrosion of ferrous, as well as inappropriately specified stainless steel elements.
- Climatic site considerations.
- Geographical moisture drive conditions.
- Winds and air-borne contaminants.
- Subgrade soils and water table level.

The above are important parameters that must be given consideration in the design of a building envelope and selection of materials used in it in order to respond to the parameters of a given building site.

Detailing

While the author acknowledges that there are certain circumstances in which detailing is subverted due to costs or understandings with contractors, all too frequently project detailing is lacking, misunderstood, incorrect, or does not provide enough detail for proper construction. The American Institute of Architects (AIA) indicates that seven of the top architects' concerns have to do with moisture penetration. Regardless of this, the author is always amazed at the lack of specific detailing in contract documents. A review of documents from major architectural firms reveals that while very standard and systematic conditions get detailed, detailing more complex interactions and intersections of materials is left to the contractor and/or in-field conditions. This is especially true on larger high-rise facilities; where often the final design of the façade system is left to a manufacturer, who gives little concern to continuity with other envelope systems and materials, especially at breaches in the façade and/or roof system. This type of detailing and architectural practice can only lead to failure of long-term building performance and potentially, legal action.

It is this architect's recommendation that details be large [scale preference 75 mm = 300 mm (3 in. = 1 ft.)], diagrammatic, and contain the use of isometrics, perspective, and multiple-phase details as necessary to impart the design solution and to assure that the interaction of building materials will work. Additionally, as architects communicate graphically, it is recommended that the designer draw, draw, and draw correctly. When an architect is unsure of the design functionality of a building envelope system, consultation with a knowledgeable industry consultant/expert that is experienced with the characteristics, limitations, and functionality of the specific building envelope material system in question is imperative.

Material Selection

Following inappropriate or lack of detailing for building performance, an additional cause of building envelope failure is the inappropriate selection of materials for the building type, function, or climatic region. A greater number of product choices than in the past are available to building designers. Lighter, more composite materials replace traditional materials. Promises of inherent favorable performance characteristics are often overshadowed by less than desirable installed attributes, resulting in unknown and unforeseen in-field performance issues subsequent to installation. Compatibility of façade component materials should be confirmed by formal testing, as all are not compatible with all substrate materials. This situation amplifies the importance of redundancy, which will be discussed further. Materials need to be appropriate for the purpose intended. Use of a barrier system in areas that receive high levels of rainfall without the redundancy of a drainage system behind it is intuitively incorrect, and should never be allowed. The City of Vancouver, for example, allowed hundreds of buildings to be installed with EIFS systems. These systems were doomed to fail because of their design and material selection.

Other material selection mistakes that the designer needs to be aware of include material compatibility, or incompatibility. For example, anodized aluminum materials should not be used in association with masonry systems with mortar, which may develop efflorescence that will damage the anodizing, as will cleaning the masonry of the efflorescence. Expansion and contraction of differential materials needs to be understood. When installed in confined spaces, expansion and contraction needs to be compensated for in the design process. It is impingent on the designer of record to research product performance, learning from past failures in projects already in place, as well as compare marketing promises against actual in field performance. Owners, designers, and contractors all need to be wary of unproven new materials. Length of use in the field is a great concern. Often the annual changes of material composition lead to concern. In the United States there are currently roofing materials in place for steep-slope roofs that promise 50-year warranties, but have been on the marketplace for less than a year. What use is a warranty if the company is no longer around after four or five years? Liability lies with the designer.

Many manufacturers offer and can provide "full" and complete systems with associated warranties. These systems work in concert with the prescribed components. Many designers tend to mix and match components from various systems and trust they will work; this is not prudent sustainable design and failure typically occurs. Many LEED certified buildings are victims of this type of design.

Realize the Importance of Redundancies

Just as there are no sets of perfect contract documents, neither is construction perfect or performed with a small level of variance. Knowing this, it should be assumed that small imperfections in all building envelope systems will occur, manifesting themselves in time. Therefore, it is highly recommended that redundancies be installed with regard to removing moisture that penetrates exterior façades of the building envelope. The design team needs to acknowledge this fact, convey it to the staff preparing the contract documents, incorporate it into the details, and communicate the importance of the concept to the bidding contractors.

What is a redundancy? It is one or more backup water- or air-barrier systems built in as a method for dealing with moisture infiltration before it reaches vulnerable materials or surfaces. An example of a lack of redundancy includes leaving termination bars at roof base flashing unprotected by counterflashing, which left unprotected, often allows moisture to infiltrate behind the base flashing. The use of a counter flashing over the termination bar is just one example of a redundancy. The cost of installing added protection during initial construction period is very small compared to subsequent repair or replacement.

The Importance of Using Gravity Correctly

Ninety-five percent of the time, water flows downhill. Those architects and designers who are dealing with the building façade must understand those occasions when and where water moves uphill. In general, the greater the slope of an element, the better. There should be no level or flat surfaces on a building façade surface. Copings, sills, thresholds, any snap-on cladding systems for window wall and window systems perform longer when installed at a slope. Horizontal elements that need to be given consideration in addition to the detailing mentioned above include roofs and concrete walks. Sloping these elements drains water away from the building. Rooftop heating ventilating air conditioning (HVAC) equipment requires protection. Once again, the architect/designer needs to understand wind effects produced when accompanied with high rain. These effects include a head of water being established on vertical and horizontal elements. Imperfections in these elements will quickly compromise the element. Additionally, it is quite difficult to construct low-slope building elements with consistent tolerances for success. Allowing for slopes of less than a quarter inch per foot is difficult to achieve even with the best contractors.

Material Interfaces

When two materials of differing composition or structural integrity meet, consideration must be given to that interface and how it will be sealed to protect against climatic effects that will continually attempt to intrude through it. The most difficult and challenging of conditions is the flush condition. The flush condition is of great concern because of tolerances involved in the different materials. For example, a fixed hollow-metal doorframe within a masonry opening involves two materials manufactured with very different physical characteristics: one is rigid and almost perfectly dimensioned; the other has some tolerance. In a critical condition, the brick could be offset from the frame up to 13 mm (½ in.) at the head with the result that cascading water would continually have an opportunity to enter the interior. Perpendicular conditions also are a concern. Wind-driven rain and head pressure can compromise these conditions.

Detailing these material interfaces must take into consideration construction tolerances that could adversely affect the installation and performance of the system. Flush surfaces not only increase the project degree of difficulty, but also its cost. A single omitted or inadequate joint, adjustable fastener, or inappropriately sized, formed, or installed accessory can lead to moisture penetration.

Continuity at transitions can be a critical element for a number of components, such as air and vapor retarders. The continuity of these types of materials should be carefully thought out and meticulously detailed. Discontinuity can result in uncontrolled and unwanted airflow that may result in energy inefficiencies, as well as condensation concerns and deterioration of building components. The designer should not leave the issue of continuity up to interpretation, but specifically define it.

Building Team and Project Approach

Assuming that a well-qualified architect/designer has been retained for the project, the appropriation of a qualified contractor for the type of project being given consideration is equally as important. Empirical knowledge by contractors who have experience, have learned from past mistakes and now know how to plan and look ahead, will prove very beneficial to owners seeking long-term performance. The owner should be budgeting accordingly for quality-built buildings.

While all businesses are concerned with the greatest value per dollar, being shortsighted in a construction process warrants increased callbacks and greater potential of marginal performance. Modern building construction, the repair and maintenance of existing facilities, in the presence of continually evolving materials and construction practices places high demands on the design community and construction trades.

With regard to value engineering, there is nothing more detrimental to the performance of the building than to evaluate the reducing of and/or changing of materials to meet a budget. Weeks, sometimes months and years, can be spent integrating materials and systems; then often within a short time systems are changed without proper research to investigate long-term effects of the changes on the numerous materials and systems that will be interfaced. Alternatives are not often integrated into the building design process. Changes are almost always more expensive in the long term than the cost of the initial construction, and the interrelationship of all materials and systems is a concern. In areas of complex detailing of the building design and approach, it is recommended to request and provide full-scale mockups, since often all issues cannot be anticipated. The majority of failures occur at the contact points between different materials. This critical review of intersections can often be reviewed and agreed upon when full-scale mockups are built. The advent of complex building envelope systems makes the fabrication of full-size mockups and their testing almost imperative for long-term performance. Why test? To insure that the materials and the methods assigned are being assembled and installed as required.

Construction

As previously mentioned, the importance of procuring a contractor with experience, enthusiasm, and quality cannot be understated. The importance of the contractor’s coordination and preplanning will be imperative to successful completion and long-term performance of the building envelope systems. In addition, the value of construction observation independent of the contractor cannot be underestimated. As indicated previously, the purpose of such independent construction observation is to determine compliance with the contract documents. This third-party observation of critical system installations is of great value, especially with components that will be buried or hidden behind subsequent overlay materials. In describing or trying to determine the value, one should give consideration to the cost of inspection versus the cost of replacement of the systems that would be observed. The adage “Inspect What You Expect” cannot be overstated.

Maintenance

While most building owners and users perform maintenance on interior surfaces, little if any maintenance consideration is given to the building envelope systems with the possible exception of window washing. Preventive maintenance of the building envelope systems provides for the early detection of concerns, which can often be handled with minor repairs, and the prevention of moisture intrusion before damages occur. Observation often performed in association with nondestructive testing and monitoring can assure building users of a safe and healthy environment as well as allowing building owners/managers to keep replacement costs manageable and allowing for budgeting for replacement and/or major repairs when necessary.

Additionally, certain building envelope systems (such as warranted roof systems) may require, as part of the warranty, that periodic maintenance be performed and documented in order for the warranty coverage to be valid.

CONCLUSION

Obtaining a sustainable building envelope, one that achieves long-term performance with energy performance characteristics is now, in this author's opinion, a national need. Architects need to start defining the service life goals of the buildings they design and then work toward these goals in the façade system(s) and material selection. Façade systems and materials must be compatible, work in concert with each other and their interfaces, and be well designed and coordinated. The drawings and specifications need to be very clear as to whom it is to provide what, and that each trade is responsible for clarifying how the work of adjacent trades is to be incorporated into their systems.

"Glitches" within the building envelope systems will develop and are a concern to designer, contractor, and owner alike. By working as a team, conditions that can lead to building envelope failure can be resolved during the construction. The following should be considered:

- respecting and understanding the design and the effects of climatic conditions;
- understanding the building process;
- detailing;
- material selection;
- realizing the importance of redundancies;
- using gravity correctly;
- understanding material interfaces; and
- providing a quality building team, construction observation and proper maintenance.

Coordinating the above items with respect to the building envelope systems, material selection, and detailing will lead to long-term, successful performance of building envelope systems, the first step in achieving a sustainable built environment. Fewer failures result in reduced building repairs, lower operational costs, lower maintenance costs, minimizing building vacancies, and increased building occupancy productivity. This allows buildings to be utilized for their intended function for longer periods of time and results in a positive interior building environment. These are the foundations on which successful, sustainable buildings are built.

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