Duke Medicine: High Performance Buildings for Extraordinary Healthcare

Audience: Designers and Builders of future Duke Medicine buildings

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The Building Envelope

Lessons Learned

During the past four decades, architectural firms, engineers, and contractors from every region of the country have helped shape our medical campus. In this period of rapid expansion, Duke Medicine has occupied and maintained millions of square feet of new construction representing many individual buildings of various form and function. Witnessing the life-cycle performance of such a diversity of buildings, design, and materials is an experience reserved for few but large institutional owners such as Duke. From this context we offer our institutional knowledge on the construction of the building envelope.

Some of these "lessons" have been hard won by our institution at the cost of significant labor and financial resources diverted to chronically leaking buildings. All of these lessons reflect a belief that high performance, durable buildings are the product of thoughtful and deliberate intent.

Roofing System Design

Few building components possess the power of the roofing system to impact facility operations. Done well, the roofing system is a reliable ally, protecting both our property and our mission. Done poorly, the roofing system is a deep and continual draw on our institution's resources -- resources that find their best use in support of outstanding patient care or cancer research, not in the funding of a premature roof failure.

Duke Medicine has established a firm rationale for roofing design that ensures the highest performance and durability for our medical buildings. In general, we promote the following principles for membrane roofing design:

1. **Favor** insulations or insulating assemblies that are highly resistant to water and physical damage
2. **Favor** roof assemblies that position the roof membrane directly over a permanent or semi-permanent substrate
3. **Favor** roof designs that prohibit or highly discourage the entrapment of water within the roof assembly
4. **Favor** membrane and insulation designs capable of in-place reuse or recycle in future roof iterations

Over time these guiding principles have produced a dramatic improvement in roofing performance on our campus. We particularly ask our designers to emphasize adaptive reuse of materials. Adaptive reuse will sharply lower future costs and will produce minimal impact on the environment and hospital operations, opportunities certain to be welcomed by future generations.

A few Duke Idioms worth a read:

- Bidding and awarding roof construction with only generic specifications and generic drawings is an invitation for substandard construction of unacceptable service life.
- Long-term, high-performance roofing can be achieved with ordinary products used in extraordinary ways.
- You get what you *inspect* -- not what you *expect*.
- Much of past roofing construction and demolition waste created by our institution could have been avoided by more forward-thinking roof designs.

The importance of thorough pre-qualification of our roofing contractors can not be overstated. This can equally be said of certain other building trades. The best efforts of competent design will be undone if not mated to competent construction. Contractor experience, safety programs, skill sets, and supervisory strength are questions of equal importance to financial stability. Next to pre-qualification, professional bid clarification is our most powerful ally. We do ourselves no favor by snatching a defective low bid. Letting an honest contractor "bleed out" financially on a project is in no one's best interest. *Wanting* to "bleed out" a *less* than honest contractor who is abusing a weak spec holds even less appeal! Duke Medicine should pay the true cost of a quality roofing installation – once. We'll pay for quality or we'll pay for poor quality. Either way, we'll pay.

Exterior Building Skin

Duke Medicine began taking more than a casual interest in exterior wall design when we realized that many of our chronic roof leaks were actually produced by wall defects. Much worse, some chronic leaks were produced by a combination of roof *and* exterior wall deficiencies! A bad roof can be removed and replaced by a more durable roof. A poorly designed or poorly constructed building façade cannot simply be replaced. It will be patched and repaired, patched and repaired, patched and repaired, with limited short-term success for the remainder of the building's life. More building owners would take an active role in skin review if they realized how much of their annual maintenance budget and labor are consumed by less than exemplary original design and construction. Our Duke education includes:

1. **Duke Stone:** From a weatherproofing and durability standpoint, nothing on campus matches the performance of the 1920's Duke Stone "mass wall" construction. Many of the building skin problems we see on campus are, quite understandably, a reflection of the mid-20th century move from mass wall construction to more economical and lighter weight cavity wall and curtain wall designs. (This is simply an observation and point of reference, not an appeal for return to mass wall construction.)

2. **Construction Drawings:** We've observed a general decline in the quality of architectural drawings and specifications for the building envelope during the past two decades of campus construction. Among our observations:

   - Skin construction drawings that are generic, incomplete, often unbuildable, and which provide little or no help with the integration of critical elements on the building skin. This condition results in the construction manager and contractor "fixing" the design in the field – often under the duress of a tight construction schedule. The final product is rarely as durable as it should be, and Duke may receive a new building that is prone to a lifetime of chronic moisture and leak problems.

   - Barrier Wall or "face-sealed" designs, which rely entirely on sealants as the single barrier to moisture intrusion. This design approach is extremely unwise for facilities with zero tolerance for moisture intrusion – such as a hospital. Designs must emphasize "redundancy" and provide a secondary drainage plane to effectively redirect water intrusion back to the outside of the wall cavity and away from the patient care environment.

3. **Vapor Barriers:** We encounter a great deal of confusion regarding the role and placement of vapor barriers within wall assemblies. Our predominant use of design firms from northern cold regions may explain, in part, this condition. In fairness, there is much debate across the country regarding the control of vapor drive in wall assemblies. Durham, N.C. is defined as a "mixed-climate" region meaning that at some point during the design year a vapor barrier will be in the wrong place. We believe that in our region the worst place for a vapor barrier is to the interior conditioned side of the wall assembly during the "dog breath" days of summer. Further, we find wall design errors which inadvertently create "double vapor barriers" by their assembly of non-permeable materials. This condition may interrupt the natural drying process of the wall, creating a significant accumulation of moisture and biological growth. The HVAC function

within the building and the variable of pressurization adds further complexity to this aspect of wall design. We urge our designers to give this issue the highest level of scrutiny on future campus construction.

4. **Air Barriers:** Actually, we'd suggest that the term "vapor barrier" should probably be stricken from our design vocabulary. Air leakage, or vapor *convection* has hundreds of times more capacity than vapor *diffusion* for the transport of moisture within a wall assembly. In the real world, the idea of constructing an "exclusionary barrier" to *anything* is folly, particularly the seasonal drive of moisture-laden air. Design energies would be better focused on strategies to eliminate or control air infiltration, realizing, of course, that 100% exclusion is impossible. Incidental moisture that does collect in the wall enclosure must be freely allowed to dry via natural processes (i.e., no more vinyl wall coverings!) This topic begs for a clear consensus from the building industry.

5. **Exterior Insulation:** On 4 of 5 recent buildings for the medical campus we have confronted a design error related to the application and assumed insulative value of steel stud and fiberglass batt assemblies. The un-insulated flanges of the steel studs are often exposed in an unconditioned wall cavity that allows the stud flanges and webs to become a thermal bridge. For this reason, ASHRAE 90.1 requires the designer to de-rate the listed R-Value of the batt insulation by 50% when used in this wall configuration. Therefore, a code sheet calling out an R-13 steel stud w/batt assembly has a functional R-Value of approximately R-6.5. Our designers have rarely picked this up. Further, we are not pleased to receive a web of thermal bridges that may create dew point events and condensation within our wall insulation. (**Note:** Recently, we have used polyurethane foam sprayed directly to the interior face of the façade on several new buildings. In addition to excellent thermal performance, this material also creates an effective air barrier.)

6. **Building Skin Water Management:** The recent LEED design trend of adding "shading" elements to the building façade can have an unintended operational impact. Solid precast or metal eyebrows over windows, for example, become collection points for airborne dirt and bird debris which rain water can flush to the surrounding building skin. Regular cleaning with fresh water and possibly harsh chemicals may be required to maintain an acceptable building appearance. Very "un-LEED," we think. In general, our designers should be mindful of the operational impact produced by the overly creative use of horizontal setbacks and reveal elements on the building façade. These features, as suggested earlier, can be dirt collectors which produce cascading dirty rain water. Of even greater concern is the likelihood of building leaks along these setbacks and ledges which can only be accessed for repair at significant hazard and cost.

7. **Building Façade Complexity:** This may be a footnote to our previous point of discussion, item number 6. The exterior appeal of our new healthcare and research buildings is a point of pride for both those who build them and those who operate and maintain them. We are very much in favor of buildings that are

architecturally engaging. Designers, however, should be mindful of the operational impact of integrating multiple dissimilar cladding materials on our buildings. (Recently, a leakage path was isolated at the intersection of four dissimilar cladding systems on one of our buildings.) While we encourage creativity, we do ask that the designer invest at least as much energy in making our buildings as reliable and durable as they are engaging and beautiful.

8. **Façade Weep Systems:** Great care must be taken to understand and protect the moisture weep devices in window and facade systems. We have observed detailed drawings and well-intentioned sealant contractors that have inadvertently defeated the operation of weep devices. The intent and function of façade weeps is a critical subject for the preconstruction conference. Buildings with curtain walls are often very challenging to detail in regard to providing redundancy or backup drainage planes. Double sealant joints between curtain wall elements will typically require some creative detailing, for example, showing the secondary joint periodically "shunted" through the primary (exterior) sealant joint with a weep vent. A mock up of this highly technical detail is critical to ensure proper execution by the contractor.

9. **Below-grade Waterproofing:** Waterproofing failures are most often remedied with much difficulty and at great cost. The highest level of scrutiny must be ensured by the construction manager and contractors during the application and protection of this system. We have observed otherwise excellent waterproofing applications rendered useless due to inadequate protection and subsequent damage during backfilling or abuse by other construction activities. Frequent inspection by the manufacturer's technical representatives during application, as well as prior to and during backfill operations, is strongly recommended.

10. **Construction Coordination:** We have seen some reasonably competent skin designs completely doomed by poor execution in the field. Sometimes a critical detail, though very attractive in plan, cannot be constructed as envisioned due to phasing conflicts not considered during design. At other times a critical detail is defeated by weak coordination of building trades. As a matter of process, the construction of a high-performance building skin requires that people communicate well and often. The construction team must identify critical weatherproofing elements on the façade. Pre-construction meetings specific to flashings and waterproofing elements are essential to confirm responsibility and coordination of trades. Full-size mockups are often vital to ensure a proper understanding of construction. Finally, the owner must have a representative to shepherd construction phasing for effective follow-through. A great deal is at stake here. If, for example, responsibility for a critical window flashing detail is missed and poorly executed, then we have a leakage path multiplied hundreds of times on our building façade. We have one chance to get this right. Professional peer review should be mandatory if these skill sets are not readily available in-house.

11. **Anticipate Future Building Maintenance:** Accessing the building skin or roof areas for maintenance or replacement of large mechanical units is routine in the life of a building. Please anticipate this in design to provide adequate and safe access for our maintenance personnel. Also, preserve access pathways for the staging of heavy maintenance and crane operations. Drive lanes and sidewalks at these access points should be designed to support heavy equipment loads.

A New Standard of Care for the Environment

Duke Medicine is committed to environmentally responsible development and innovation. Much of the innovation promoted by the green building movement is simply good business and common sense. Nonetheless, we realize that until these green innovations become common practice and familiar to our contractors, we may receive cost data that is prohibitive. Novelty and uncertainty will seldom produce favorable pricing. It is precisely at this point where Duke Medicine and our construction partners can provide valuable leadership.

Our Engineering & Operations group combined with friends in the Nicholas School of the Environment and Earth Sciences at Duke University are developing a green research and exhibition project on the medical campus. Site features will include: "Design for Disassembly" strategies, green roof trials, storm water reclamation, photovoltaic power generation, green (vegetated) façades, a first-in-class leak detection system for green roofs, and possibly a test site to evaluate the effectiveness of "smog eating" PC titanic concrete additives. Our goal is to identify top resources for Green building while expanding our knowledge of economic and design strategies. The benefits of some professional collaboration along this line would extend beyond the campus of Duke Medicine. Tp

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Footnotes…

Next Step

We hope to use this "Lessons Learned" format as a platform for future iterations of the Duke Medicine design and construction series. This initial issue takes a broad swipe at building envelope issues and is more general in content. Future issues may, for example, offer best practice strategies for the design of individual elements of the building enclosure as well as other building systems. Through the years, our institution has collaborated with some of the best minds in building design and construction. We are in discussion with a number of these good folks and other respected sources in hope that our combined experience will deepen the value of a "Lessons Learned" series on the Duke campus.

Closing Thoughts on the Year that was…

2007 has been a wild ride for any hapless soul curious enough to stick his or her head into the sustainability or green building pipeline, particularly at an academic center. You sort of feel like that mosquito in Gary Larson's old Far Side comic strip -- engorged to the size of a golf ball from tapping an artery while your little mosquito friends scream "Pull out! Pull out!" Opinions abound regarding what or who is driving the green movement, opinions ranging from smartly informed to rather cynical and not particularly helpful. Operational or maintenance types (the author included) have in the past tended toward the latter. Cynicism, unfortunately, can be an occupational hazard in our pragmatic profession.

On occasion, our green cynicism has not been without cause. We've smirked, for example, when new LEED buildings touting "cool" roofing membranes have these same eco-friendly membranes designed into roof assemblies we know are prone to early failure. A LEED applicable roofing system that fails prematurely because of inferior quality or misapplication does not look very sustainable buried in a landfill. This, of course, applies to any building component or system.

Take heart. More than a few of us operational types are becoming rabidly (yes, I meant to use rabidly) green. And we're making a lot of new young friends, a number of whom have interesting hair and way too many bumper stickers. Sure, some of their ideas may prove larger than life, but the tsunami-like move toward environmentally responsible design was launched on their youthful passion and energy. But you dare not discount them for their youth. Their green movement is producing real economic benefits on the Duke campus, inspiring, for example, a 2007 roof replacement that mustered a materials salvage rate of 90%, diverting 718 tons of solid waste stream. Salvaged materials from this effort, including 296,000 board feet of XPS insulation, have been reused in new roofing construction on two of our buildings.

Really, take heart. This movement that was seeded by bumper stickers and "greener than thou" marketing blurbs is quietly creating a new generation of building owners who will expect quality and high performance. An early sign is the building owner who prefers 30 or 40 years of roof life – with or without "salad" topping! For 2008, ***Durability*** is back on the menu. Let's hope it's more than just seasonal fare.

Come see us… We promise not to bite. **:)** Tp

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