The Four D's

Integrating the D's in Building Envelope Design

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In 1999, Canadian consultants Don Hazledon and Paul Morris published a seminal paper describing "The Four D's" of weathertight building envelope design: deflection, drainage, drying and durability (or decay resistance). Every building envelope assembly represents a unique integration of the four D's by a designer who selects from widely varying materials and systems in response to external parameters that include budgetary limitations, aesthetic considerations, fire resistance, structural loads, local climate data and interior moisture loads.

Some designs can be successful even if the architect emphasizes only one of the four D's. Consider, for example, a building with a very wide roof or deck overhang that shelters an exterior wall from virtually all rainfall. This emphasis on rainfall deflection allows the architect to specify a wall assembly with reduced drainage, drying and durability performance.

On the other hand, some designs fail because one or more of the four D's has been sacrificed unduly. That's what happened with the well-publicized failures of barrier exterior insulation finish system (EIFS) assemblies. They failed due to the lack of any provisions for drainage of incidental leakage through the surface barrier of the insulated cladding assembly. In this case, not having flashings and building paper or housewrap can result in a level of moisture accumulation that eventually overwhelms the limited durability of the underlying sheathing and framing materials.

The owner is replacing the original aluminum windows (above right) with new metal-clad wood windows (above left). Note the severe deterioration in the redwood shakes.

Over the past 80 years the most dramatic (and perhaps least recognized) modification to typical exterior wall designs may have been the extreme reduction in drying performance brought about by the use of interior vapor barriers, wall cavity insulation and panelized sheathing. In our society's quest for energy efficiency, our well-insulated and airtight exterior walls no longer are heated from the interior during winter months. In addition, excess moisture that may accumulate within some of our exterior siding and cladding systems often no longer has a secondary drying route into the building interior. This usually is due to the presence of vapor-retarding materials intended to block the outward movement of interior heat and/or moisture.

Upgrading the D's

As a result of these reductions in drying performance, it's necessary for exterior wall designers to upgrade the efficiency of at least one of the remaining three D's: deflection, drainage and durability. As an example, let's consider the photographs of a home constructed in 1952 in a Northern California locale with an average annual rainfall exceeding 40 inches.

The owner is replacing the original small single-paned aluminum casement windows with larger double-paned, double-hung windows (*photo at left*). The severe deterioration of the original old-growth redwood shakes required total replacement at this weather-exposed elevation. It also is important to note that, while the redwood shakes had been attached to one layer of #30 felt, no effort had been made to flash the original aluminum windows.

However, in the photo to the right, we see that, despite the extensive decay of the redwood shakes, there is absolutely no water damage at the wood sheathing or framing. To understand this phenomenon, we need to evaluate the four D's of the original wall design:

- **Deflection**: the relatively small roof overhang provided only a fair degree of rainfall deflection.
- **Drainage**: the failure to install a gutter at the roof and the lack of any flashing at the original windows represents poor drainage performance.
- **Drying**: the exterior wall has no insulation, no interior vapor retarder and numerous open spaces between the wood sheathing boards. As a result, the design provides excellent drying performance from both the interior (during wet winter months) and the exterior (during the dry summer season).
- **Durability**: the old-growth redwood shakes exhibited good durability, as evidenced by their overall survival for more than 50 years in a wet climate below a gutter-less roof. In addition, the heavily built window frames, which were manufactured in the post-World War II era when aluminum was plentiful and cheap, continued to provide exceptional durability.

Despite poor drainage and only fair deflection properties, the assembly provided more than 50 years of complete weather-resistive performance primarily because of continual drying at the back side of the durable redwood shakes that covered the wall.

Considering the potential long-term financial savings that could accrue from lower wintertime energy bills, would it be wise to stuff batt insulation into this wall assembly? Only if we counteract the new wall assembly's reduced drying properties with significant improvements to its deflection and/or drainage performance.

Removal of the deteriorated redwood shakes reveals no water damage at the wood board sheathing or stud framing.

Balancing the D's

In the case of the Northern California home, the owner opted to improve drainage performance by installing a gutter at the roof overhang and an integrated flashing assembly at each new window. Upon review of the excellent condition of the original wood sheathing and framing, the owner also decided to forego any effort to insulate the wall. He didn't attempt to lower his wintertime energy bills out of fear that the wall's reduced drying performance could lead to moisture infiltration, decay and mold growth. The owner also decided not to heed the local building inspector's recommendation to re-sheath the wall with plywood to increase the structure's ability to resist earthquakes.

Modern designers and builders do not have the option of ignoring local energy or structural codes to maintain good drying performance. In addition, some common exterior wall products, such as paper-faced gypsum sheathing, do not exhibit a high degree of moisture- or mold-resistive durability. Therefore, to offset these reductions in two key aspects of the four D's, good designers and builders recognize that they must increase their focus on the deflection and/or drainage properties of the wall design. It is our experience that most cases of mold and moisture damage at the roof or exterior walls can be traced back to a lack of attention by the designer or the builder to the four D's of modern building envelope design.