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The 4 D's of Building Envelope Design

In 1999, Canadian consultants Don Hazledon and Paul Morris published a seminal paper describing 'The 4 D's' of weather-tight building envelope design: ***deflection***, ***drainage***, ***drying*** and ***durability*** (or **d*ecay resistance***). Every building envelope assembly represents a unique integration of the 4 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 4 D's. For example, consider 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 a lesser degree of ***drainage***, ***drying*** and ***durability*** performance.

On the other hand, some designs fail because one or more of the 4 D's has been sacrificed unduly. For example, consider the well-publicized failures of 'barrier EIFS' (exterior insulation finish system) assemblies due to the lack of any provisions for ***drainage*** of incidental leakage through the surface barrier of the insulated cladding assembly. In this case, the lack of any 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.

Arguably, over the past 80 years the most dramatic (and perhaps least recognized) modification to typical exterior wall designs has 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, during rainy periods, excess moisture that may have accumulated within some of our exterior siding and cladding systems often no longer has a secondary ***drying*** route into the building interior due to presence of vapor-retarding materials intended to block the outward movement of interior heat and/or moisture.

As a result of these reductions in ***drying*** performance, it is incumbent upon the modern exterior wall designer 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 following two photographs of a home constructed in 1952 in a Northern California city with an average annual rainfall exceeding 40 inches.

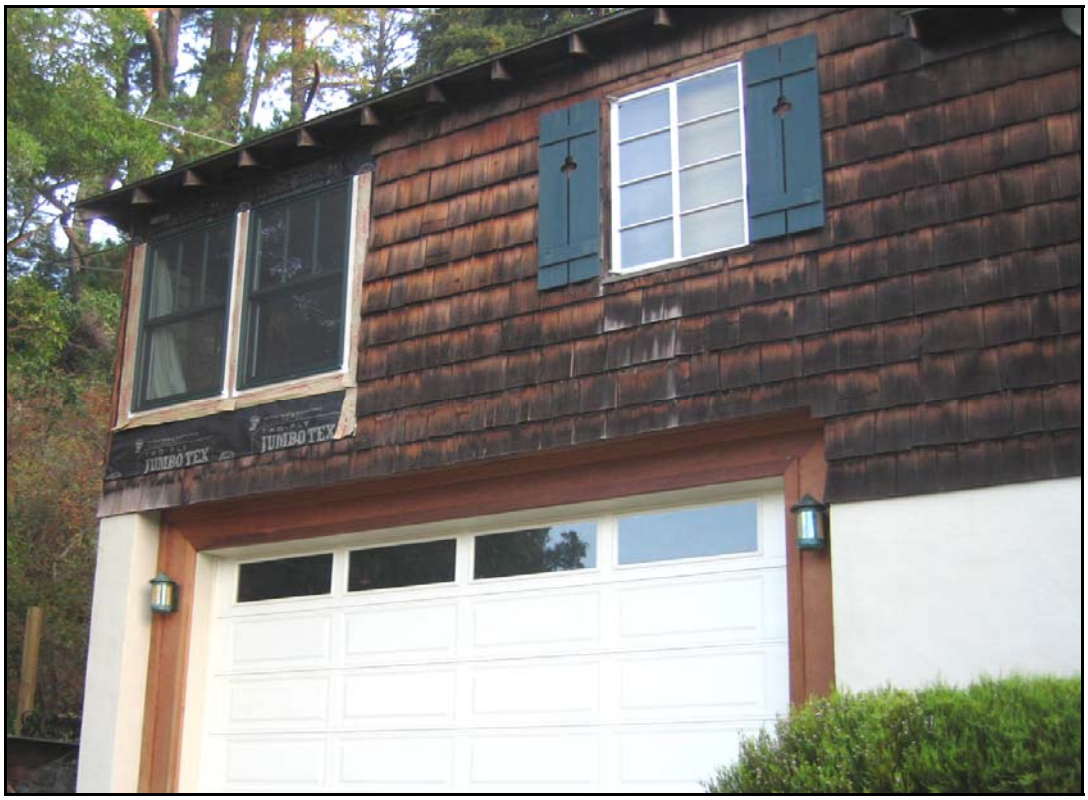

Photo 1 – Owner Is Replacing the Original Aluminum Windows (at Right) with New Metal-Clad Wood Windows (at Left). Note the Severely Deteriorated Redwood Shakes

Photo 2 – However, Removal of the Deteriorated Redwood Shakes Reveals No Water Damage at the Wood Board Sheathing or Stud Framing

In Photo 1, we see that the owner is replacing the original small single-paned aluminum casement windows with larger double-paned double-hung Marvin windows. Note the severe deterioration of the original old-growth redwood shakes, which 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 Photo 2 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 consider the 4 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.

In short, despite poor ***drainage*** and only fair ***deflection*** properties, this energy-inefficient wall assembly provided more than 50 years of complete weather-resistive performance due primarily to continual ***drying*** at the back side of the durable redwood shakes that covered the wall.

Now, 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.

In this case, the owner opted to improve ***drainage*** performance by installing a gutter at the roof overhang and an integrated flashing assembly at each new window. However, 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. In other words, he elected not to 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.

Further, these ***fears of reduced drying*** performance caused the owner to ignore the local building inspector's recommendation to fully sheath the wall with plywood panels in order to increase the structure's ability to resist earthquakes.

In contrast, designers and builders of new homes 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***. To offset such reductions in these two aspects of The 4 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 4 D's of building envelope design.

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Lonnie Haughton is a Certified Access Specialist for determining compliance with state and federal accessibility regulations and is one of the less than 500 individuals nationwide who have been certified by the International Code Council as a Master Code Professional. Lonnie's ICC certifications include Building Inspector (California Building Code); Building Inspector (IBC); Building Plans Examiner; Accessibility Inspector/Plans Examiner; Fire Inspector I and others.