Opportunities for Improving Overall Building Performance through the Selection of Natural Hazard Resistant Attributes for Building Enclosure Materials

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Abstract

Over the past decade the insurance industry became aware of the limitations that exist when attempting to specify and select residential building materials that are resistant to natural hazards. The industry noted that there was, and continues to be, a lack of satisfactory materials available to meet design requirements for high winds and hail. Additionally the lack of proper test standards, appropriate materials, adequate installation knowledge, or suitable code requirements appears to lead to increased damage (losses). Several trends have combined to accelerate loss severity trends; the population shift to the hurricane prone coastal regions, increased size, complexity, openness, percent fenestration, increasing quantity of plumbing and mechanical system components. Future research directions need to consider a more holistic approach to envelope design and durability issues. Entire communities need not be vacated due to damage from tornadoes, hurricanes, or wildfires, nor require the replacement of every roof due to hail storms. By ensuring that building envelops remain intact, the impact of a natural disasters can be greatly reduced.

Keywords: Envelop, Performance, Insurance, Mitigation, Natural Hazards

Introduction

This paper approaches the subject of building envelop performance in residential structures with a perspective that is broader than that of mere insurance issues. It should be noted that the views expressed in this discussion are those of the author and not necessarily those of State Farm.

The consequences of building envelop failures can range from simple cosmetic damage to the total destruction of the building. Due to exterior and interior finish damage, mechanical system destruction, post-event questions of structural integrity, and contents damage, a structure may be considered a "total loss" from an economic standpoint even though a significant portion of the structural system may remain intact after a design level event. Traditionally, residential building codes have only utilized engineering-based research to address the hazard resistance of the main structural system of the home while providing mostly anecdotally-based regulatory instruction for the selection and installation of building envelop components.

Many conventional (non-engineered) design practices utilized for residential structural systems are also based on "rules of thumb" and not on a robust body of sound research knowledge. The

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engineering community appears to lack consensus on whether and how the building envelop should be considered; some treat it as a part of the structural system, some consider it architectural and ignore it. But, an increasing number of engineers have concluded that building envelop design is essential since a direct correlation has been shown to exist between its performance and the damage (losses) sustained by wood-frame buildings (Rosowsky et al. 2003). Building envelop materials are often considered in an independent fashion as roofing materials, siding materials, or fenestration products, and not holistically as part of the total building system.

Typical building envelop failures may include: roof covering damage (partial and complete), siding damage, fenestration damage, and damage to other attachments (gutters, awnings, chimneys, antennas, vents, and exterior HVAC equipment). By far, the most serious of these failures tend to be the roofing and fenestration failures. The failure of either of these components can lead to damage to the interior of the house. If accompanied by high winds, potential failure of the entire structure due to internal pressurization is possible (Institute for Business and Home Safety 2000). If followed by rain, serious damage to building contents, finishes, and structural components may occur.

The types of events that damage building envelop materials include: rain, thunderstorms, straight-line winds, hail storms, tornadoes, hurricanes, snowstorms and ensuing ice dams, wildfires, and earthquakes. In many cases, post-event repair response may be limited due to restricted site access, insufficient available manpower, and scarce construction materials. When missing doors and windows or the holes in roofs and walls can not be patched in a timely manner, the damage from subsequent wind and rain storms acerbates the initial damage as well as invites looting and theft. As was seen after Hurricane Andrew, even a small breach in the envelop can lead to significant water damage (Smith 2002).

While insurance typically covers the cost to replace the structure, it may also include disposal / demolition costs, replacement of the contents, and additional living expenses. As landfills reach capacity and environmental concerns are more closely evaluated, the cost of the disposal of damage-generated debris, as well as re-construction produced waste, will need to be factored into the total cost burden natural disasters bring to bear on society. Estimates of the value of the interior contents of many single family residences continues to rise thereby escalating the financial impact of the disaster. It must also be remembered that the cost of a natural disaster to society is greater than that of the physical damage alone and considerations must include social impacts as well.

Current State of the Art

Hurricane Andrew, Hurricane Iniki, the Northridge Earthquake, and the Oakland Hills Wildfires revealed to both the insurance and building construction industries that then current construction practices were inadequate to address natural disasters. Insured losses for Hurricane Andrew alone were over 250% of the industry's pre-event "worst-case scenario" estimates (Kelly et al. 1999). In an attempt to better understand the damage that occurred, as well work toward mitigating the effects of future natural disasters, the insurance industry embarked on a number of programs. The Institute for Business and Home Safety was established as a nonprofit association to engage in communication, education, engineering and research in order to reduce deaths, injuries, property damage, economic losses and human suffering caused by natural disasters. Property and Casualty insurance companies began supporting academic research programs. Some invested in building construction / loss mitigation research programs. Insurance industry trade associates began supporting code improvements, adoption, and enforcement efforts. In addition many within the industry began public education and policy initiatives.

In the course of attempting to communicate appropriate construction techniques for disaster resistance, it became increasingly clear that there was a lack of building envelop performance research data available. The knowledge-base that existed for residential housing materials, especially building envelop products, was typically limited to anecdotal reports or limited studies. An obvious case in point was that of impact resistant roofing materials. Prior to the insurance industry's involvement, a test standard for residential roofing products did not exist. Underwriters Laboratories' UL 2218 standard was introduced in 1996. With no standard to serve as a baseline, there was no way to differentiate between products.

Even with this small first step forward on roofing impact resistance, issues remain. The UL 2218 standard only tests new products at typical interior temperatures – outdoor temperatures, "per-storm temperature fluctuations," and the effects of weathering and aging have not been incorporated into the test standard (Graham 2000). Due to these limitations the roofing industry has been critical of the test standard, yet little to no non-proprietary information about how roofing materials respond to these environmental forces exists. Hail damage is so severe in Texas ($5.3 billion for 1994 to 2000 (Herzog 2002)), that regardless of the lack of available performance data, the Texas Department of Insurance (TDI) has mandated insurance rate (premium) discounts for homeowners who install impact resistance roofing products.

Another instance of the lack of building envelop performance research data was revealed when State Farm attempted to specify building materials for wind resistance for its "Good Neighbor House" in Deerfield Beach, Florida. The design called for the house to be designed to resist a Category 4 hurricane (156 mph wind speeds and the associated pressures). The building codes in southern Florida called for homes to be designed for wind speeds of up to 110 mph (Category 2 hurricane) and therefore there was an abundance of building products available that met those requirements. While the engineer was quite capable of designing the structural system for the higher wind speeds problems developed when attempting to select adequate building envelop materials (Figure 1).

Upon completing the design it was found that it was possible to design and build the structure (footings, walls and roof structure) intended to withstand a 156-mph wind speed. Doors, garage doors and windows were not available at the design pressures created by higher wind speeds. This is because building codes do not require stronger building products, so they were not made. Roofing products had not been tested to the higher wind speeds since the building code in south Florida only requires testing up to 110 mph. Since it was not possible to achieve a 156-mph design for window and door products or for the roof membrane, special attention was given to improving the most vulnerable points (State Farm 2001).

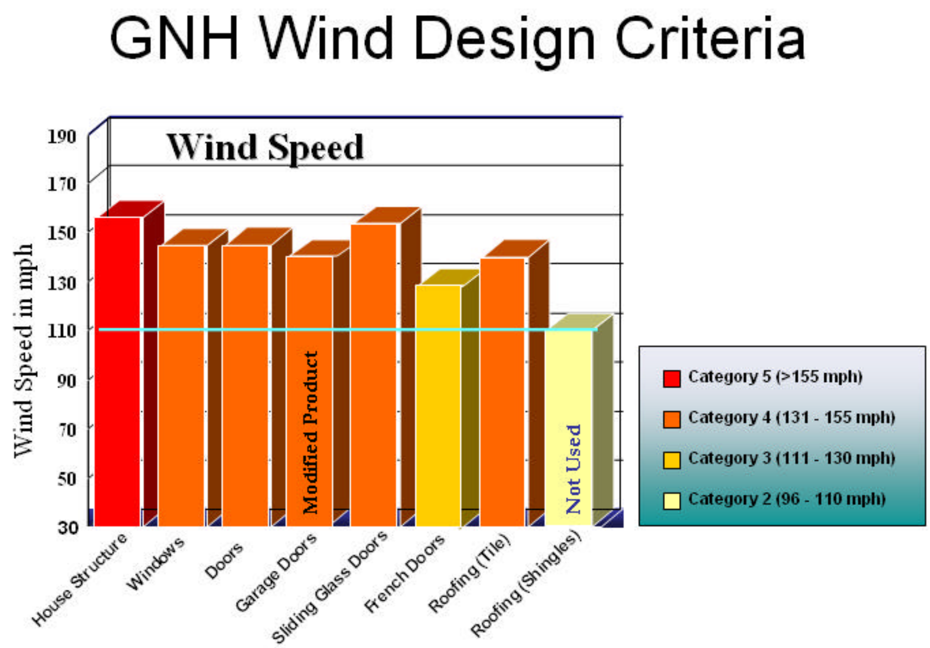

Figure 1 State Farm Good Neighbor House Envelop Features,

Note: Siding materials were not addressed as the house was designed with a stucco finish directly over the structural concrete walls.

The windows, doors, garage door and roofing materials available in the marketplace could resist a mid-level Category 4 hurricane, but could not meet the wind speeds and pressures criteria the designers had hoped for. When questioned regarding the lack of products available for those parties wishing to build at a higher performance level than code minimums, the manufacturers cited lack of consumer demand, higher costs, and competition. The building code and standards referenced therein drive what is available in the marketplace. This led to the realization that it was virtually impossible for consumers to demand better performing buildings as they simply could not be built with the products and materials available.

Standards such as ASCE 7-98 (ASCE 1998) provide specific guidance on wind and seismic resistant design only for the simplest of structural shapes (e.g., a regular plan with a simple gable or hip roof). "These are not typical of most wood-frame structures, particularly those (higher-end structures) built along the coast" (Rosowsky et al. 2003). In addition modeling of the forces that affect residential structures (typically wood frame) is limited. Figure 2 shows the wind pressures associated with a single wind direction/speed on a simple gable end roof (Vickery 2002). On complicated multi-gable / multi-dormer roofs, common in many new homes, the complexity of the forces that affect roofing materials will substantially increase. Add changing wind directions and speeds (hurricanes, tornadoes, micro-bursts) and the scenario quickly become exceedingly complicated.

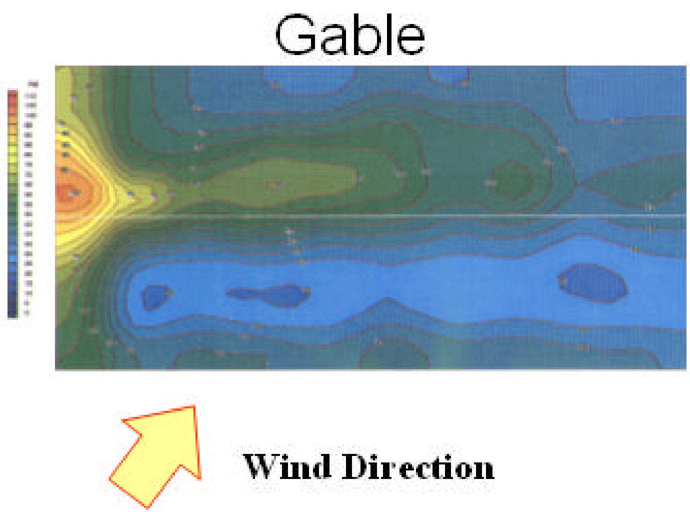

Figure 2 Roof Aerodynamics: Wind Pressure Loads, Courtesy of Peter Vickery, Ph.D.
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Future Research Directions

Future research directions need to consider a more comprehensive approach to building envelope design and durability issues, as well as present a consequence-based approach to product selection decision making. Recurrent damage is an indication that opportunities exist for research-based product design improvements and/or installation technique improvements. The long term performance of and the potential impact of failures in envelop components are two areas that deserve focus and attention. Building envelop failure consequences should be addressed as a community-wide issue. Damage investigations after Hurricane Andrew "revealed that most building damage was caused by building envelop failure" (Smith 2002). When envelop failures occur it is often the result of a natural disaster that has wide-spread impact. Moreover during windstorms, in addition to the direct physical damage to the subject structure, impact debris generated by the property may damage adjacent buildings.

Frequently, and especially when it concerns low-rise residential construction, structural system issues are disassociated with building envelop issues. It has been shown that building envelop failures can lead to compromised structural integrity, impaired habitability, and significant repair expense. Understanding and quantifying the cause and effects of this cascade of damage would assist quantifying the cost/benefits associated with improved envelop performance. The creation of a performance reliability index would assist in the selection of products and materials appropriate for the risk (hazard). Work along these lines has begun in the seismic risk community.

Research initiatives that provide performance data on the effectiveness of various types of envelop materials and installation techniques are critical to the building construction and insurance industries, as well as to the general public. The average expenditure on homeowners insurance has increased almost 50% in less than a decade (Hartwig 2003). These increases are due in part to the industry's attempt to better correlate losses and rates. Due to both increased population and building inventory, the Property Claim Service (ISO / PCS) estimates that if the "Great Storm of 1950" were to occur today, there would be over 1.5 million claims (properties damaged) and $1.3 billion in losses. Similarly, modeling of the 1938 Hurricane shows that a reoccurrence would affect over 41 million properties and loses would exceed $25 billion (Kerney 2003). As rates increase, consumers may begin to understand the link between poor building envelop performance and the effect it has on the amount they pay for insurance.

The following areas would benefit from additional research, standards development, and quantification of performance level attributes:

?? Enhanced wind resistant roofing products (higher wind speeds, durability)
?? Enhanced wind resistant siding products (higher wind speeds, durability)
?? Enhanced wind resistant soffit materials (higher wind speeds, durability)
?? Enhanced wind resistant attachments (vents, false-chimneys, gutters, awnings)
?? Enhanced wind resistant garage doors, entry, patio/sliding glass, and French doors
?? Improved hail / impact resistance roofing products
?? Improved hail / impact resistance fenestration products (especially skylights)
?? Flashing and proper detailing (especially in light of the more complicated roof designs allowed by light frame trusses)
?? Consideration of the loading of envelop materials on the structural system
?? Consideration of the of failure envelop materials/systems on the structural system
?? Fenestration (impact resistance from windborne debris, water infiltration)
?? Earthquake resistance considerations for siding (especially brick veneer)
?? Wildfire resistance of all exterior envelop materials (fire resistance of siding and roofing, heat resistance of fenestration products, ember infiltration resistance of roof vents)

Many of the decisions made when selecting exterior finishes (building envelop components) are made for aesthetic or first-cost reasons with no (or little) concern for the impact those decision will have on the hazard resistance of the structure. Anecdotal reports from the recent California wildfires have drawn attention to the increasing popularity of vinyl windows – windows which were reportedly melting and thereby admitting fire to the interior of the structure.

With every product selection decision made, the consequences of those decisions should be able to be clearly understood by the material specifier, builder, and consumer. Those consequences will only become clear when sufficient research has been conducted on the impact of all natural conditions to which a product may be subject, and when this information is readily available in an easily understood or universally communicated method (e.g. "Energy Guide" stickers). This type of information would help to alleviate the disconnect that exists between the expectations and objectives of homeowners, builders, engineers, and insurers as well as the surprise and accusations that follow due to poor disaster performance.

First steps in this regard have been taken, a case in point being IBHS' "Fortified for Safer Living" program which quantifies the disaster resistance of certain building characteristics

(IBHS 2003). However, additional research is critical to support efforts such as this and to quantify the performance attributes of all newly developed products.

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