The Next Step for AF&PA/ASCE 16-95: Performance-Based Design of Wood Structures

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The concept of improving building performance has, for all practical purposes, always existed at what might be deemed the societal level. If engineered systems do not perform as society and users deem acceptable, these systems do not continue to be constructed and are eliminated over time. The inadequate systems are replaced by improved ones whose performance is expected to be more acceptable to the stakeholders and to society. In modern times this evolution manifests itself as revisions and updates to prescriptive design codes, which typically are anywhere from one to seven years apart.

The impetus to formalize performance-based design (PBD) has its roots in Housing and Urban Development’s “Operation Breakthrough” of the 1970s (NBSIR 1977) whose goal was to enable product innovation via industry. However, the wood industry, particularly home building, did not fully embrace innovations for increased performance since they often resulted in higher costs. Subsequently, these higher costs were not tolerated by the marketplace and thus the innovations were not implemented. A recent Structural Engineering Institute (SEI) special project entitled “Keeping Pace with ASCE 7” examined the reliability indexes inherent in the ASCE16-95 standard (ASCE 1996; Bulleit 2006). The ASCE 16-95 committee of the SEI of the American Society of Civil Engineers (ASCE) has the option to move beyond load and resistance factor design (LRFD) and spearhead the next generation of standards for wood design, specifically a performance-based standard. Following the aforementioned SEI special project, the SEI/ASCE committee on Reliability-based Design of Wood Structures embarked on a two-year special project entitled “The Next Step for AF&PA/ASCE 16-95: Performance-Based Design of Wood Structures.” This paper presents the progress made by that project committee and is the first in a series of general papers that will present a PBD framework for wood structures over the years to come. The performance levels, first articulated at the 1st Invitational Workshop on Performance-based Design of Wood Structures (van de Lindt 2005) are (1) occupant comfort; (2) continued occupancy; (3) injury/life safety; (4) general structural integrity; and (5) manageable loss/damage. Each discussion will address the hazard characterization, performance descriptors that align with the five performance levels, model complexity required for analysis, design procedure verification, and how these performance-based analyses can be extended to design. This discussion order is summarized in Fig. 1.

Performance-based design has been defined in a variety of ways, including an engineering approach based on: (1) specific performance objectives and safety goals of building occupants, owners, and the public; (2) probabilistic or deterministic evaluation of hazards; and (3) quantitative evaluation of design alternatives against performance objectives. However, PBD does not prescribe a specific technical solution (Ellingwood 1998). Perhaps a more practical definition, related to seismic design, is that given by Nathan Gould of ABS Consulting: “PBSD (Performance-Based Seismic Design) is the seismic design methodology of the future. It allows the design team to work together to determine the appropriate levels of ground motion and performance objectives

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**Fig. 1.** Organization of each hazard within Part I of the SEI special project
for the building and nonstructural components in order to meet the owners expectations.”

However, these definitions and visions for PBD are provided in a general building sense and not specific to wood frame construction. Wood structural systems, particularly light frame wood structures, require consideration of several issues that structures made of other materials such as steel and concrete do not face.

**Issue 1: Current Design Philosophy**

Much of current wood frame construction is not designed, but rather is conventional or prescriptive, using essentially “rules of thumb” and standard construction practices rather than engineering calculations for each structure. Thus, the application of PBD is, in a way, significantly beyond current wood construction practice in many (but not all) cases. This is not true for all wood construction, however (e.g., in seismic regions, particularly California, design calculations are explicitly required). This type of engineered design is also evident in unique custom homes (i.e., high-end wood construction).

**Issue 2: Value of Wood Structures**

Most of wood frame buildings, particularly residential, are valued at least at $1 million and many are on the order of several hundred thousand dollars. The median price of a new house in the United States in September 2008 was $218,000. Note that this cost includes the price of the lot/land and varies significantly from region to region. According to the National Association of Home Builders (NAHB) the average size of a U.S. home is approximately 2,300 square feet and throughout the 1990s the majority of U.S. homes were three bedrooms with 60% of homes having four to six rooms total (i.e., living rooms, kitchen, dining room each counted as a room). The cost of performing a PBD is, at this point, significantly more costly than a standard prescriptive design, and therefore the impact on the engineering component of the building cost for wood buildings is very significant. This issue should be thought of as a challenge for the wood engineering research community, specifically how to develop prescriptive-type techniques to achieve specific performance objectives, all the while keeping in mind that this may violate the most general definition given by Ellingwood (1998) above. On the other hand, if one considers that current housing mortgages in the United States currently total $12.4 trillion (Freddie Mac 2008) and are projected to exceed $20 trillion by 2015, improving the performance of the housing stock will provide these structures and communities with resiliency and longevity.

**Issue 3: Wood Construction Culture and Quality Control**

The current culture of wood frame building construction, particularly residential construction, does not lend itself well to change. Much of the construction procedure is not well documented, particularly for details of stick-built construction. The use of prefabricated wall panels may help to reduce and change this culture, which is already being pursued by many homebuilders. In addition, consider the differences between the fasteners in a wood shear wall and the bolts in a steel moment connection. Both assemblies provide the lateral resistance for the building, but for the steel connection an exact number of bolts is used and tightened in a prescribed manner. For the wood shear wall built on site, fastener spacing is “eye-balled” rather than measured; further, fasteners are often overdriven, and can miss the wall stud entirely diminishing the capacity of the wall (Rosowsky and Kim 2004). It should be noted that this is not a design code issue, but it must somehow be accounted for either through considerations of additional uncertainty in wood wall modeling or inspection practices. Left unaddressed, wood frame buildings may not satisfy performance objectives—not because the performance based design approach is insufficient, but because quality control issues make it impossible to tell what is satisfactory and what is not.

Although there are obvious roadblocks to implementation, PBD of wood structures may have the greatest chance of success under certain conditions. Such conditions are (1) modular construction; (2) tract home communities (e.g., offering performance upgrade packages much the same as current kitchen appliance upgrades); and (3) highly customized homes where issue 2 (value of wood structures) does not have as significant an impact. The ability to apply PBD to a large portion of the wood structure stock can be realized if issue 2 is addressed. It is unlikely that exactly the same PBD methods used by the steel and concrete design communities can be ported directly for use in wood buildings. Issue 3 and specifically the level of inspection that is performed for wood structures is likely to be an issue as PBD develops for wood structures.

As previously mentioned Fig. 1 shows the layout of this paper. Each hazard must be characterized in a meaningful enough way that it can be applied to analysis and design. Once a hazard is characterized, quantifiable performance descriptors must be defined, or at least identified to allow an analyst to determine if performance objectives are met. The values that will be compared to the performance descriptors will come from a numerical model whose complexity must be described for each hazard. Finally, the verification of the performance metrics as well as the extension to design for these concepts is presented.

Table 1 presents example performance expectations for each performance level and natural hazard combination. Although the hazard type changes from one load to another, the performance expectation should be defined consistently, to the extent possible, to ensure a consistent level of risk. One tool to estimate costs based on failure is assembly-based vulnerability (ABV), which has been used for seismic analysis (Porter 2000; Pei and van de Lindt 2009) and flood (van de Lindt and Taggart 2009). Although life safety is addressed herein, it is assumed within this project that ASCE’s standard “Minimum Design Loads for Buildings and Other Structures” (ASCE 2006) life safety levels will be met or that level of life safety exceeded by the PBD.

**Fragility**

A concept that will be used throughout this paper is fragility. Fragility is essentially a conditional probability of failure (loss) of a structural member or system over one or more input variables. For example, the probability of roof sheathing loss due to a demand exceeding the design capacity can be expressed as

\[
P[\text{sheathing loss}] = \sum P[\text{sheathing loss} | \text{Demand} = x]P[\text{Demand} = x] \tag{1}
\]

where demand is the force (or other demand) on the component; and \(x\) is a given demand. The summation is over all the demands. The first term in the summation, i.e., the conditional probability, is defined as the fragility (Ellingwood et al. 2004; Rosowsky and Ellingwood 2002).
Table 1. Performance Expectations and Corresponding Performance Descriptors for Different Hazards Proposed

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Occupant comfort</th>
<th>Continued occupancy</th>
<th>Life safety</th>
<th>Structural integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic</td>
<td>1% Interstory drift (ID)</td>
<td>2% ID</td>
<td>3–4% ID</td>
<td>7% ID</td>
</tr>
<tr>
<td>Snow</td>
<td>Roof leaks due to ice, etc.</td>
<td>Damage is sufficient enough to allow exposure to weather.</td>
<td>Local not collapse. Ice building up and falling from roof. Strength analysis.</td>
<td>Total roof system collapse. Strength analysis.</td>
</tr>
<tr>
<td>Durability</td>
<td>Little or no moisture load.</td>
<td>Low moisture load.</td>
<td>High moisture load.</td>
<td>Very high moisture load.</td>
</tr>
<tr>
<td>Flood</td>
<td>Not applicable.</td>
<td>Water recessive by pumping or natural means possible. Ventilation possible/moldabatement. No sewage backup, no structural damage, no water entry to mechanics and elect.</td>
<td>No structural damage. Flooding may prevent egress. Flooding depth is significantly high.</td>
<td></td>
</tr>
</tbody>
</table>

Performance-Based Seismic Design

This subset of PBD has received significant attention over the last 10 to 15 years, and particularly the past five years as a result of three damaging and deadly earthquakes: Loma Prieta in 1989, Northridge in 1994, and Kobe in 1995. In the latter two earthquakes, both fatalities and financial losses associated with wood structures were considered unacceptable by any standard. The CUREE-Caltech ( Consortium for Universities for Research in Earthquake Engineering—California Institute of Technology) Woodframe project, a FEMA-funded project to examine current state-of-the-art wood frame construction in California and make recommendations for improvement, set the groundwork for performance-based seismic design (PBSD) of wood buildings in the United States. Rosowsky (2002) developed mass charts for wood shear walls based on interstory drift requirements as part of that project. Filiatrault and Folz (2002) proposed extending Priestly’s (1998) original direct displacement design (DDD) concept to wood frame buildings, which was recently extended to multistory wood buildings by Pang and Rosowsky (2007). Van de Lindt and Walz (2003) demonstrated the determination of wood shear wall performance based on reliability indices for several different cities around the United States. Nonstructural components in wood frame buildings, which have been shown to play a major role in the dynamic response and, thus, performance of wood frame buildings, were investigated experimentally (Filiatrault et al. 2004; van de Lindt et al. 2007a). More recently, efforts are being made as part of the NEESWood project (see [http://www.engr.colostate.edu/NEESWood/] for details) to develop a tiered PBSD philosophy with the focus on midrise buildings (Pang et al. 2008). Also, van de Lindt et al. (2008) developed a (hysteretic) probabilistic system identification approach. Pei and van de Lindt (2009) also have proposed a loss-based PBSD approach for wood frame buildings that allows the building owner (and/or other stakeholders) to use expected loss with their loss management objectives. Li and Ellingwood (2007) determined the reliability of wood frame residential construction under a spectrum of possible earthquakes by looking at drift limits.

Focusing the discussion on wood frame structures up to approximately three to four stories in height, which are common for multifamily buildings, consider again Table 1. The majority of these various performance expectations, with the exception of personal content damage, appear to be best correlated with interstory drifts. Collapse tests in Japan, although not strictly on western-style wood frame buildings, have indicated that soft-story collapse requires very large interstory drifts on the order of 15%. For two- and three-story wood frame buildings, a working interstory drift value of 7% is proposed in Table 1. The other values are relatively consistent with ASCE 41-06 (2007) for PBSD.

Analysis methods for PBSD use nonlinear hysteretic models that account for degradation during reversing cycles and provide an accurate estimate of interstory drift (ID). Models like this include full structure finite-element models built using software such as ABAQUS, as well as pancake-style models such as SAWS (Folz and Filiatrault 2004a,b) and three-dimensional (3D) models such as SAPWood v2.0 (Pei and van de Lindt 2009). Seismic designs based on performance expectations are being conducted currently within the research community but not yet within the practitioner community for wood buildings.

Performance-Based Design for Wind

Wind hazard is expressed by a wind speed probability distribution for a standard averaging time (e.g., 3 s), exposure (e.g., C-open), and elevation (e.g., 10 m). Because of a lack of statistics, hurricane winds are simulated probabilistically from fundamental climate modeling principles and the resulting wind speeds at specific mileposts are derived from the wind field model. These wind speeds are postprocessed statistically and are used to develop design wind speed maps for the ASCE-7-05 “Minimum Design Loads for Buildings and Other Structures” (2006). The statistics of parameters for wind load equations defined in ASCE-7 can be obtained from a Delphi study (Ellingwood and Tekie 1999). The Weibull distribution was found to be an appropriate model for hurricane wind speed prediction (Li and Ellingwood 2006).
The majority of studies to date have focused on fragility as a function of the design wind speed. This design wind speed is usually the ASCE 7-05 standard (2006) 3-s gust and fragilities can be characterized for various components and subassemblies based on these wind pressure models. Posthurricane disaster surveys have shown that the building envelope is the part of residential construction that is most vulnerable to hurricane-induced damage (NAHB 1993). Once the envelope is breached, the building and its contents are increasingly likely to suffer severe damage from water or wind effects. Ellingwood et al. (2004) investigated light-frame wood structures using fragility curves for both wind and earthquake hazard, demonstrating the development of fragilities for roof sheathing, truss spacing, and roof sheathing nail patterns. Lee and Rosowsky (2005) stated that breach of the building envelope and resultant water penetration is the leading cause of financial losses in high winds. Li and Ellingwood (2006) developed hurricane fragility curves for key components that are essential to maintain the light-frame wood building envelope. These components are roof panels, roof-to-wall connections, windows, and glass doors. The failure modes for windows and glass doors can be either excessive wind pressure or projectile impact.

For PBD of wood frame structures to wind load it is envisioned that the standard wind loading (e.g., ASCE 2006), could be used when site specific data are not available. Proposed performance descriptors associated with PBD for wind are component and assembly-based in that the most damage occurs to the roof and cladding materials. Again, referring to Table 1, some example damage descriptors associated with the various performance expectations are shown. If the building envelope is breached during a high wind or hurricane event the majority of the damage occurs from wind-driven rainwater intrusion. In fact, a moderate level of gable end damage (i.e., loss of less than a full sheathing panel) to a structure during Hurricane Katrina in 2005 resulted in water damage equal to the purchase price of the house five years earlier (van de Lindt et al. 2007b).

Perhaps the closest parallel for PBD for wind can be drawn from seismic design, since losses are the major focus for PBD and not exclusively life safety, which, as discussed earlier, is addressed by ASCE’s standard 7-05 (2006). PBD is, by and large, felt by most researchers to be a philosophy that allows performance improvement by the incorporation of system-level behavior using system models. However, in wind engineering most failures occur at the component and subassembly level. A recent paper by Ellingwood et al. (2006) highlights the current status and future challenges for PBD, including wind. In that paper it was stated that guidelines for PBD for wind do not currently exist in the United States. It was also stated that extreme winds (with the exception of tornado winds) are not viewed as a life safety issue in force-based design primarily because of the opportunity for prior warning, which is not true for other hazards such as earthquakes. Finally it was articulated that analysis techniques are needed that model both load- and non-load-bearing walls as an integrated system.

In PBWE, considering our performance expectations and damage descriptors in Table 1 (van de Lindt and Dao 2009), at a specified peak gust wind speed (e.g. say 90 mph), an owner might expect no damage and no water intrusion. For a well-designed and constructed residential structure this may typically be the case provided wood is in a nondecayed state and fasteners are spaced appropriately. For another level of protection the owner might expect to be provided life safety at 170 mph, meaning (for example) no total loss of the roof.

The modeling of wood structures to wind load, especially light-frame structures, can be done on an almost routine basis, as in the assumptions built around such design-related activities as assigning loads to diaphragms and shear walls. However, analysis also can be done on a more fundamental and specific basis, such as trying to predict connector forces and stresses in sheathing and framing. The required level of analysis for PBD for wind depends on what response parameter may be of interest. In the realm of PBD, a key limit state is the attachment of the sheathing to the framing, as well as the adequacy of windows and doors. As mentioned, loss of sheathing or breakage of windows or doors allows unpredictable air flow and water into the structure that may compromise the stability of the diaphragms and shear walls. Thus, a reliable model must be able to capture the localized effect of wind on specific portions of the roof and walls. In the ideal, this means that, having a full probabilistic time and spatial characterization of the wind, a model must be capable of including the time-dependent spatial behavior of the sheathing/connector attachment to the framing over the external surfaces of the structure. In short, this approach mandates that the model has to recognize the continuity in the sheathing, the variability in the quality of the attachment of the sheathing spatially, and how, if at all, the resistance of the connectors to negative pressures is affected by their simultaneous assistance in making the shear walls and diaphragms work structurally.

**Performance-Based Design for Snow**

Life safety has been the primary performance objective for snow hazard. However, economic losses due to snow can be severe, even when the life safety objective has been met. For example, the March 1993 East Coast storm cost an estimated $1.75 billion (O’Rourke and Wrenn 2007). In 1998, a major storm affected more than three million people in the eastern United States and Canada and caused major damage. Thus, immediate occupancy and collapse prevention performance objectives should be included in a PBD framework as well as life safety.

Limit states, or conditions in which the structural system ceases to perform its intended functions in some way, associated with performance descriptors for snow load must be defined to carry out PBD. System limit states can be either deformation related or strength related. Examples of limit states for occupant comfort or immediate occupancy are excessive window or door header deflection, ice dams producing a breach of envelope or roof leaks, or excessive ice build-up causing ice slides that endanger people and property outside the structure or the structure itself. Partial failure of a roof member or supporting member (e.g., wall stud) with or without building envelope breach would be a threat to life safety. Partial roof failure that compromises structural integrity or complete roof system collapse, whether or not that leads to whole building collapse, should be used as the limit states to provide collapse prevention and assure structural integrity.

Currently, LRFD wood design is component-based. To truly examine the effect of snow on wood-frame construction, system models may be required. Simplified beam-spring models (e.g., Bulleit and Liu 1995; Liu and Bulleit 1995) may be appropriate for system analysis. An analog beam models the roof sheathing as a continuous beam across the truss or rafter. Each spring models the sheathing, connectors, and truss or rafter interacting as a partial composite member or T-beam. Such system models will allow analysis of partial roof failure, although extensions of this type of model, based around work such as Cramer and Wolfe (1989), likely will be required for truss systems. From a design stand-
point, a closed-form limit state approach for system performance is desirable. For instance, using a system factor for analysis of roof system based on analysis of a single roof truss is more feasible from a practitioner’s point of view. The percentage of roof area damaged due to partial roof collapse could be used as a quantitative measure. Modeling roof snow load and response is further complicated by the effects of roof geometry and type on drift loads, snow sliding, and system behavior. Exposure conditions and building orientation also affect drifting and snow removal by wind. Snowdrift modeling is needed to consider all the effects just cited. Another factor to consider is the effect of thermal conditions on snow load and ice dams. Furthermore, the effect of rain-on-snow events on total load and on ice dams cannot be ignored; weight of snow may increase dramatically when rain saturates the snow, and thus rain on snow models will be necessary.

Extension of performance-based analysis to design for snow load is a challenge in terms of computational effort since subassembly or system level models may be required to check whether a safety or collapse prevention performance objective can be achieved. For practical reasons, engineering design needs to be based on physical parameters that can be related to the performance limit states. Damage surveys and insurance data would be the best source of information to develop desired performance levels. Truss roof structural models suitable for PBD can be validated using data from sources such as Wolfe and McCarthy (1989) or Wolfe and LaBissoniere (1989). The acceptance criteria could be at the component level for the immediate occupancy objective, while the subassembly level (ideally the system level) should be considered for life safety and collapse prevention.

The proper definition of design snow loads for various performance levels is another issue. Snow loads associated with various return periods (e.g., 30-year for occupancy comfort, 75-year for life safety, and 100-year for system collapse prevention) may need to be considered, which are similar to those used in performance-based earthquake engineering. For the maximum considered snow, the 475-year return period (or 10% probability of exceedance in 50 years) could be considered to model a very rare snow event or represent repeated snow events that lead to significant snow accumulation. The maximum annual roof snow load can be determined as a product of ground snow load, which can be modeled as a lognormal distribution, and the ground-to-roof conversion factor, which is also lognormally distributed. Thus, maximum annual roof snow load can be modeled by a lognormal distribution with site-dependent statistics. Other probability distribution functions that might be considered for annual maximum snow load are largest extreme value distribution type I (Gumbel) and largest extreme value distribution type II (Frechet). Ground and roof snow load statistics have been investigated by various researchers (e.g., Ellingwood and Redfield 1983; O’Rourke and Stiefel 1983; and Taylor 1985).

**Performance-Based Design for Durability**

Since almost all durability issues in wood frame buildings are tied to moisture (including most insects), as a first attempt, all performance descriptors should be linked to moisture level (load) in the wall cavities, attic, crawl space, and inside the house. Referring to Table 1, one can see that the current performance descriptors are general in nature. It is clear at this point that these need to move from qualitative to quantitative in order for PBD for durability to proceed. Durability as discussed herein is limited to long-term and unnoticed or ignored moisture accumulation from the humid-

ity of exterior and interior air (vapor diffusion, air leakage), plumbing leaks, precipitation (rain, snow, ice dams, reverse vapor drive) or soil moisture. Air moisture loads can be determined by selecting a reference year having, for example, a 30-year return period from the documented range of exterior (weather) and interior relative humidity conditions, and temperature differentials across the building envelope (Dalgleish et al. 2005). Precipitation moisture loads can be determined by selecting a reference year having, for example, a 30-year return period from climate data (e.g., NOAA), including direct rain and wind-blown rain or snow, plus temperature/precipitation conditions causing ice damming and reverse vapor drive. These loads may be offset by drying conditions after precipitation events, but drying should be accorded less weight than wetting. Soil moisture loads can be determined from climate data (e.g., NOAA) for the same prescribed return period; however, these loads will also be influenced by local soil type and water table.

For the purposes of developing a model for strength loss of wood components, the decay process under fluctuating conditions can be divided into three stages: (1) establishment, (2) growth and decay, and (3) survival under adverse conditions (Nofal and Kumar 2000; Nofal and Morris 2003). Time to establishment is the rate-limiting step. Steps to establishment and threshold moisture contents for growth and decay of *Coniphora puteana* (the celllar fungus) on sapwood of European wood species have been determined through extensive work at VTT in Finland (Viitanen 1997b). These data have been used to develop preliminary damage function for wood components (Nofal and Kumar 2000; Nofal and Morris 2003). However, the Finnish results need to be confirmed for Canadian and U.S. wood products. In addition, the work needs to be done using fungi prevalent in buildings in North America. Some progress has been made in this area (Morris and Winandy 2002; Clark et al. 2006). Finally, the impact of small amounts of decay on the performance of complete systems needs to be evaluated. Again, some progress has been made in this area (Melencion and Morrell 2007), but further work is required.

As with strength loss, a model for the development of mold growth should contain three phases: (1) establishment, (2) growth and sporulation, and (3) survival under adverse conditions. Time to establishment and threshold moisture contents for mold growth on sapwood of European wood species has been determined through extensive work at VTT in Finland (Viitanen 1997a; Viitanen and Oijanen 2007). The Finnish results have been supplemented by data on Canadian and U.S. wood products (Yang and Bisson 2004; Yang 2007). However, data need still to be developed for nonstill air conditions. Furthermore, the relationship between mold growth in wall cavities and mold spore concentrations in the living space needs to be determined (Fazio et al. 2005). The second type of model should be a probabilistic model of insect attack events. Such a model has been developed by Australian scientists (Leicester et al. 2003; Leicester and Wang 2004); however, further work needs to be done to develop similar model for the United States.

**Performance-Based Design for Flood**

Flood hazard differs from earthquakes, wind, and snow in that loss reduction is dealt with through zoning and insurance regulations. However, there are certain instances where it is advantageous to demonstrate the effect of relocation, elevating, or wet flood proofing. As such, flooding hazard needs to be characterized in at least the following three ways: (1) flood depth, (2) water velocity, and (3) flood duration. Another factor that should even-
ual costs of repair. Some data may be available from FEMA based on one would need to compare the calculated damage with actual costs of repair. Some data may be available from FEMA based on flood damage claims. A single flood could provide a significant amount of data from various building types as well as various flood depths.

To perform a design for flood based on performance expectation, all the costs associated with a certain flood level and duration would need to be summed. A computer program for loss estimation from flooding was developed by Taggart (2007). The software uses the same logic as ABV for earthquake loss estimation developed by Porter (2000), but simply as a function of flood depth instead of spectral acceleration. Design would consist of a comparison between the expected cost savings versus cost of the improved construction (or retrofit) approach. This might be as simple as raising grade level or as complex as building an elevated structure on columns (e.g., wood piles in coastal areas) for a new building, and replacement of siding and raising appliances for an existing building.

**Conclusion**

The current status of PBD for earthquakes, wind, snow, durability (moisture and insects), and flood has been summarized herein. Some examples of research, completed, ongoing, or needed, have been provided. In order for AF&PA/ASCE 16-95 to move to a performance-based standard, two specific events should be put in motion. First, the current ASCE 16-95 committee should finalize the standard. Second, the committee should be reinstituted/reinvented to begin development of the performance-based standard for wood construction. The current ASCE/SEI Committee on the Reliability-based Design of Wood Structures served ASCE 16-95 in their development of the standard and can continue to serve during the development of the performance-based standard, either under a different or the same name. The expectations and choices within the document can be articulated by the committee, but a large body of research will be needed to provide numerical models and correlations between damage descriptors from those models and realistic building performance.

**Acknowledgments**

This paper resulted from the Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE) special project entitled “The Next Step for ASCE 16-95: Performance-Based Design of Wood Structures.” Their support of the Committee on the Reliability-Based Design of Wood Structures Special Project is sincerely appreciated. The 1st Invitational Workshop on Performance-Based Design of Wood Structures was held in Fort Collins, Colorado, in 2005. Those workshop participants (list available on page 11 at http://www.engr.colostate.edu/~jwv/) are acknowledged for their helpful discussion. Philip Line’s (AF&PA) contributions to the durability section, and Dan Wheat’s (UT Austin) contribution to the wind modeling section of this paper are both gratefully acknowledged.

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JOURNAL OF STRUCTURAL ENGINEERING © ASCE / JUNE 2009 / 617


