# Advocating for Performance-Based Design

**Report to the Structural Engineering Institute Board of Governors**

**Submitted by:**

**Task Committee on Performance-Based Design**

**April 5, 2018**

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# PERFORMANCE-BASED DESIGN

### SEI Vision for Performance-based Design

*The Structural Engineering Institute (SEI) of ASCE believes that society and stakeholders to the construction industry will benefit when performance-based design (PBD) principles are applied during the design of structures. Performance objectives will improve clarity of design requirements, quality, innovation and communication with owners and the public. Performance-based design methods will likely be applied to buildings and structures that are critical to a community or individual owners; have unique or unusual structural systems; incorporate novel materials and design approaches; or advance resilience, sustainability, robustness, and conservation in the built environment. To this end, SEI will support engineers who pursue and advance performance-based principles; engage, educate and encourage stakeholders; and develop tools, standards, and codes that advance implementation of performance-based design.*

## CHAPTER 1 – MISSION STATEMENT

### Introduction

We, the structural engineering community, are confounded by a situation we created for ourselves.[1] As structural engineers, we operate in a design environment with easy access to information, have the ability to collect and analyze more data than we have ever had in the past, and have access to robust and reliable analysis and design software. Nevertheless, we are prevented from fully leveraging these advantages by prescriptive codes and standards that restrict innovation and are increasing prescriptive requirements at an unsustainable rate.[2] In an era when we face multiple demands on our designs – safety, economy, serviceability, sustainability, robustness, and unreasonable schedule demands – we are constrained to follow a prescriptive path to a solution that often does not optimally satisfy expectations.

Although nearly all modern design specifications are targeted to achieve some level of performance, most structural design today is not performance-based. Rather, typical design procedures evaluate design acceptability through conformance to prescriptive criteria on materials, configuration, detailing, strength, and stiffness. Such criteria are deemed to result in structures capable of achieving acceptable performance without clearly defining the performance expectations. Furthermore, the engineer using such prescriptive procedures does not explicitly verify the ability of the structure to achieve the desired performance.

As a result, structural engineers currently are not able to apply their full capabilities to the design process. We are evolving into masters of the code, who add value by being able to negotiate the

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[1] Appendix A – How We Got to Where We Are

[2] Appendix B – An Industry Conundrum: Ever Increasing Size and Complexity of Codes and Standards - A Contradiction to the Goals of Performance-Based Engineering?

complexity of prescriptive provisions rapidly, rather than by applying indispensable creative and innovative solutions to multi-faceted structural engineering problems. As a result, the societies we serve are not getting maximum value from their limited resources of time, money, energy, and materials. Rather, they are getting designs that are constrained by prescriptive codes that are generic, with uncertain reliability because design by prescription neither quantifies nor directly evaluates performance.

How do we provide for straightforward designs of routine structures if the profession moves to performance-based principles? There are at least two ways: 1) prescriptive provisions and 2) separate design approaches for more complex structures. The prescriptive documents would address the routine structures that are designed. The performance-based documents would address the complex structures that justify a higher level of analysis and design.

**Performance-Based Design by Definition**

*Performance-based design is a process that enables the development of structures that will have predictable performance when subjected to defined loading*.

Performance-based design (PBD) turns the traditional design paradigm upside down in the sense that the required performance is the starting point for the design. Considering the desired performance of the structure and selecting the scenarios that match the goals for structural function in the presence of a specific hazard, the designer works toward achieving that stated, desired goal. The performance of the design is demonstrated through analysis, simulation, prototype testing, or a combination thereof.

Performance-based design is founded on the premise that structural systems and the nonstructural systems they support, must meet specific performance objectives. The basic steps are as follows:

- Establish the performance objectives,
- Conduct initial design, and
- Verify performance through analytical simulation, prototype testing, or a combination thereof.

Defined performance objectives are key to the process, because they establish the expectations for the design. Performance objectives may be qualitative when working with clients or building owners, but engineering practice requires quantitative criteria for design and evaluation. Such performance objectives most often include statements of the likelihood that a damage level or service state will be exceeded over the structure's life or if a specified event occurs. Examples of both types of performance objectives include the following:

- Qualitative Performance Objectives
    - The structure should have a low probability of being unusable following a design level event.
    - Occupants should have a high probability of being safe and able to exit the building given design level earthquake.
- Quantitative Performance Objectives

- The structure should have less than a 10% chance of collapse given the occurrence of the Maximum Considered Earthquake.
- Members or connections should have less than a $3x10^{-5}$ chance per year of structural failure as a result of live loading.
- Not more than 1 wind event in 10 years should cause swaying troubling to occupants.

By starting with the end goal in mind, structural engineers have more flexibility and opportunities to add value, as well as to develop innovative solutions. With performance objectives set in advance, the engineer develops a design that can be verified through analytical or physical means. This establishes the mechanism by which structural performance can be assured. Once performance is verified against the performance objectives, the design can be completed, and implemented with confidence.

**Advantages of Performance-Based Design**

Performance-based design offers several advantages over prescriptive design[3]. First, properly executed performance-based approaches enable desired performance to be attained with demonstrated confidence and reliability. Second, since the performance targets (or objectives) for the design are explicitly defined, communities and individual decision makers can select the performance level(s) that are appropriate and satisfies the applicable criteria. Third, since performance is evaluated directly as part of the design process, engineers need not be limited by requirements to conform to prescriptive solutions, thereby allowing for innovation and the use of new design solutions including new materials and systems.

These advantages will enable the structural engineering profession to achieve the following:

- Declare the expected performance of individual building designs.
- Innovate to address today's infrastructure problems, involving existing and new materials and systems, as well as to develop designs that support future paradigms of resilience and sustainability.
- Influence on broader public aspects, beyond the individual structure, to include roles and impacts at the system, community, and regional scales for public safety, welfare and resilience.[4]
- Advance the role of the structural engineer to the level where it is an informed and critical partner in the community and within the design team process, enhancing value for the public and private sponsors.

This is a process that is unfamiliar to many engineers and other professionals and stakeholders in the construction industry. The process demands more of engineers, encouraging continuing research and development and advances in engineering process. While not every structure will warrant the method, with time and exposure, performance-based design processes will become an accepted protocol for structures that can benefit from this practice.

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[3] Appendix C – The Case for Performance-Based Design
[4] Appendix D – Resilience-Based Performance Standards for Buildings and Lifeline Systems

**The Charge to SEI**

Fulfilling the SEI Vision for Performance-based Design will require strong leadership from the SEI Board of Governors. To change the design paradigm will take time – many years, if not decades. While a full list of detailed recommendations is included in this report, a summary of activities that SEI must support to advance PBD include the following:

- Identify collaborations and partnerships within the social, economic, natural and built environments that can be leveraged so that ongoing PBD activities can be fully aligned.
- Promote PBD principles through education and engagement of professionals and stakeholders to the design process.
- Develop a consensus framework, or umbrella approach, for PBD that can guide ongoing and future PBD documents and committees.
- Actively pursue development of PBD documents with code authorities and agencies.

The performance-based design principles must be developed into functional standards that all stakeholders can understand, endorse, and execute to their mutual benefit and the benefit of society in general. Structural engineers need to replace the typical practice of writing prescriptive provisions that direct how we perform every incremental step of the design, with a process that defines the performance requirements for design and defines the process for confirming satisfaction of performance requirements. All stakeholders – owners, developers, elected and public officials, design professionals, contractors, financers, insurers, attorneys – must be educated about the values returned by giving design professions the ability to solve problems creatively and the responsibility to declare expected solutions in terms of usable metrics-based approaches. Structural engineers must be educated in the new skills they will require when designing to performance-based codes, and must establish effective methodologies to achieve quality in the project. And perhaps the greater challenge is for the profession to decide which projects should be designed by performance-based approaches, develop the content of performance-based codes, and tackle the task of developing them.

## CHAPTER 2 – THE STATE OF THE PROFESSION: PRESENT STATE OF PRACTICE AND IMPEDIMENTS AND BARRIERS TO PBD

Aspects of PBD currently are being employed by designers. However, the use of the principles is limited to certain hazards, building types and selected non-conforming existing buildings. To move beyond this subset of structures, the profession must address several basic impediments to encourage widespread acceptance of PBD[5].

**Present State of Practice**

[5] Appendix E – Present State of the Practice: Technical and Educational Challenges and Needs

The current state of professional practice with regard to the use of performance-based design in the US is fractured along the lines of design loading and the type of structure being designed. Many of the prescriptive requirements in these codes and standards are based on past experience. The summary of the present state of practice presented below reflects this fractured nature of PBD in practice.

- **PBD of Buildings for Seismic**
    - **New Buildings**[6]**:** Since the early 2000s, the basis for performance-based seismic design (PBSD) of new buildings has used the performance approaches developed for the seismic rehabilitation of existing buildings and contained in *ASCE 41 Seismic Evaluation and Retrofit of Existing Buildings*. PBSD is also used in the design of new buildings to reduce the code-specified, capacity-based requirements for members that are intended to remain essentially elastic. Finally, PBSD can be used to provide other performance targets, such as functional performance for a specified seismic hazard level. These alternative performance targets are established by the project's owner in conjunction with input from the design team.
    - **Existing Buildings**[7]**:** A significant number of seismic rehabilitation design of an existing building utilizes PBSD either by the approaches provided by ASCE 41 or through the use of other existing building guidelines.
    - **PBSD Tall Buildings:** PBSD guidelines, especially for the design of tall buildings, have been available since 2010. The two most prominent documents are the Pacific Earthquake Engineering Research Center Tall Buildings Initiatives (PEER TBI) Guidelines and the Los Angeles Tall Buildings Structural Design Council (LATBSDC) Tall Building Guidelines.
- **PBD of Buildings for Wind**[8]**:** The use of Performance-Based Wind Design (PBWD) is in its infancy for buildings due, in large measure, to the complex analysis that must be done for the interaction between the buildings cladding and its structural system. Thus, most designs completed to date using PBWD have been bridges and other transportation structures that are not subjected to these interactions between elements.
- **PBD of Non-building Structures**[9]**:** The use of PBD for the design of non-building structures is virtually nonexistent in the United States. Current design practice for structural engineers is primarily based on the use of consensus codes, industry standards, and internal owner-company standards that provide minimum life safety goals and a mixture of performance goals.

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[6] Appendix F – Current State of Performance-Based Seismic Design
[7] Appendix G – Performance-Based Design of Existing Buildings
[8] Appendix H – Performance-Based Design for Wind Loading
[9] Appendix I – Performance-Based Design of Non-building Structures

- **PBD of Bridges**[10]**:** The current American Association of State Highway and Transportation Officials (AASHTO) code is largely a methods specification. The framework for code development and implementation has led code writers to favor the prescription of calculation procedures as a means for achieving consistent outcomes across the US for the standard bridge types addressed in the Code and consistency in application. The lack of definitive performance criteria within the Code associated with these engineering methods is intentional and a significant hurdle for a general performance-based design implementation. For those structures that are not specifically addressed in the Code, particularly long span bridge structures, PBD procedures are generally applied for wind and seismic design. Wind tunnel-based confirmation of performance criteria are typically specified for major bridges. Seismic design based on the AASHTO Guide Specification for LRFD Seismic Design of Bridges has elements of PBD that are applied at the discretion of the agency directing the bridge design.

- **PBD for Fire Design**[11]**:** Performance-based structural fire engineering (PB SFE) is an internationally, fast-growing field of engineering where the design of the fire protection strategy and structural detailing of a building is based on calculating the structure's behavior under realistic fire scenarios. While current practice in the United States is primarily prescriptive in nature, PBSFE has been used on many major international projects and is beginning to have an impact on building design in the U.S. This is particularly true as architects conceive more complex designs and engineers have an increased understanding of structural fire response from recent events including the World Trade Center collapse and the Windsor tower fire in Madrid.

- **PBD for Nonstructural Components**[12]: The current state of the art is generally inadequate to provide predictions of the performance of nonstructural components with sufficient accuracy to support PBD. For the foreseeable future, desired performance will more commonly be achieved through good detailing and equipment testing dictated by prescriptive requirements rather than enhanced analyses.

### Impediments and Barriers to Performance-Based Design[13,14,15,16]

A number of impediments and barriers exist to the adoption of performance-based design (PBD) by owners, building officials, suppliers, and the structural engineering profession. These impediments and barriers fall in to several categories: lack of knowledge, lack of proficiency, and resistance to change.

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[10] Appendix J – Bridge Engineering and Performance-Based Design
[11] Appendix K – Performance-Based Design Issues for Fire Effects on Buildings, Bridges and Other Structures
[12] Appendix L – Some Thoughts on the Application of Performance-Based Design Concepts to the Seismic Design of Nonstructural Components
[13] Appendix M – Performance-Based Requirements: Meaning, Limitations, and Ways Forward
[14] Appendix N– Opportunities for the Advancement of Performance-Based Design (Engaging Stakeholders)
[15] Appendix B - An Industry Conundrum: Ever Increasing Size and Complexity of Codes and Standards - A Contradiction to the Goals of Performance-Based Engineering?
[16] Appendix I - Performance-Based Design of Non-building Structures

- **Lack of Knowledge:** Most of the advances in PBD have occurred in the area of seismic design. Design for live loads, wind, and snow is still mostly based on prescriptive design provisions. Furthermore, performance objectives, particularly for Risk Category III and IV buildings and non-building structures, are not well defined. Many structures are considered to be part of essential facilities, hazardous facilities, important facilities, high consequence facilities, or mission critical facilities. For these types of facilities, the performance goal is the maintenance of function. The loss of function of these structures can have catastrophic consequences, including substantial loss of life. Maintaining function may mean remaining operational, limiting downtime / business interruption, or maintaining containment in the event of extreme environmental loading. How one meets these functional requirements is different for each type of structure. Meeting these functional requirements requires a knowledge of how the structure and the facility containing the structure are designed, operated, and are expected to perform.

  An additional challenge in using PBD is the lack of knowledge of PBD among owners of buildings and non-building structures. Many owners, insurance providers, and the public do not understand the performance levels provided by codes and standards and assume that code compliant systems and buildings will perform satisfactorily for a design event.

- **Lack of Proficiency:** When a performance-based design approach is used, the designer is not executing the building code methods and prescriptions throughout the design. Often the designer will need to apply new analysis and design techniques, materials, or systems which have no previous track record and for which there are no consensus guidelines. This application requires greater knowledge of engineering process, competence in reliability and statistics, and design by first principles. The ability to operate in this environment requires a broader skill set than that for applying prescriptive methods in a code. It also requires that the sanctioning agencies and licensing boards have a means for assuring the public that engineers engaged in these efforts have the education and experience to do so. The risk of deferring to PBD for those who are not technically qualified possible is that the design will not perform adequately.

- **Resistance to Change:** Engineers can be averse to change. There are some who raise concern about the wisdom of removing long standing prescriptive language from our standards and *not* continuing on a path of adding more and more as time goes on. Some engineers focus on public safety and believe engineers must be told exactly what to do. Exposure to litigation will limit some who are reluctant to engage in PBD. Others believe that there is a subset of buildings that are not well served by prescriptive requirements and benefit from the proper use of performance-based engineering. .

  Not all structures need performance-based design to be efficient, sustainable, and robust. Those characteristics, however conservative, can be achieve using prescriptive standards. The vast majority of structures are repetitive and routine, for which routine performance expectations can be achieved following prescriptive rules[17]. How do we provide for straightforward designs of routine structures if the profession moves to performance-based principles for the structures that will clearly benefit? Also, many firms

[17] Appendix O – Designing the Other 95%

will tend to favor conventional methods of determining compliance with building codes due to increased costs or capabilities required to conduct PBD at present. However, this paradigm could change as methods and practices improve.

Code enforcement officials might be reluctant to accept PBD because staff and technical expertise might not be adequate to perform evaluations. Hence, third-party reviews likely will be important components to the implementation of PBD[18].

While PBD is applied for some specific and discrete project types, its use is not widespread or commonly accepted as a general design protocol. To facilitate the acceptance of PBD for those projects where it can be beneficial in establishing a superior design outcome, SEI must understand and work to overcome the known barriers and impediments.

## CHAPTER 3 – ONGOING PERFORMANCE-BASED DESIGN ACTIVITIES

This initiative to advance performance-based codes and standards in the industry is not new. ASCE, SEI, and other related organizations have a variety of initiatives in progress, all of which SEI should understand, and in some of which SEI should engage.

**ASCE**

ASCE is actively evaluating opportunities for performance-based design (PBD). During the spring of 2017, ASCE held Performance-Based Design Roundtable sessions as part of the ASCE Grand Challenge, during which the organizers collected information from ASCE Institutes and engineers engaged in development of performance-based guidance. According to the announcement for the roundtable sessions, the scope is to conduct the following study:

"Performance-Based Standards (PBS) is one of the more nuanced and long-term focus areas of the Grand Challenge. To explore shifting standards within the industry, the Industry Leaders Council (ILC) is hosting two roundtables. The first roundtable will focus strictly on exploring the role of performance-based standards in the civil engineering industry. The second one will focus on life cycle cost analysis (LCCA). Life cycle approaches and processes are already being used and the discussion will focus on how to enhance and encourage more of these activities within the industry."

The organizers reported on the outcome of the roundtables in an article in Civil Engineering magazine[19] and informed ASCE as it pursues the Grand Challenge.

**ASCE/SEI**

[18] Appendix P – Peer Review and Performance-Based Design

[19] Civil Engineering Magazine, Meeting ASCE's Grand Challenge: Performance-Based Standards, December, 2017.

Technical committees and standards committees within ASCE and SEI are engaged in PBD activities. Technical committees with interest in this area can be divided into the following three groups:

1. Committees that are focused on performance-based design:
   1.1. SEI Performance-based Design of Structures Committee
   1.2. SEI Task Committee on Performance-based Design of Tall Buildings Under Wind
   1.3. ASCE Committee on Performance-based Wind Engineering
   1.4. ASCE Infrastructure Resiliency Division, specifically the Risk and Resilience Measurement Committee (developing community-based performance goals)

2. Committees that have a significant interest with past or ongoing activities in PBD:
   2.1. SEI Fire Protection Committee (developing performance-based guidance for structural fire engineering, including Appendix E of ASCE 7-16)
   2.2. SEI Aesthetics in Design
   2.3. SEI Fatigue and Fracture Committee
   2.4. ASCE Committee on Sustainability

3. Committees with multiple members working in the PBD area:
   3.1. SEI Multi-hazard Mitigation Committee
   3.2. SEI/ASCE Technical Council on Life-cycle Performance, Safety, Reliability and Risk of Structural Systems
   3.3. Task Group: Risk Assessment of Structural Infrastructure Facilities and Risk-based Decision Making.

Some SEI standards committees are advancing PBD. Among them are the following:

1. ASCE/SEI 41 Seismic Rehabilitation is a performance-based standard in its entirety.

2. ASCE/SEI 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures sets performance criteria in Chapter 1 and explicitly permits the use of PBD approaches as an alternative to the prescriptive loading criteria contained elsewhere in the standard. Based on work of the related technical committee, ASCE ASCE/SEI 7-16 added its new appendix (mentioned above) on performance-based design for fire. Going forward during the next cycle, the wind subcommittee of ASCE/SEI 7 is considering provisions for wind design.

**Other Organizations**

We are aware of relevant activities outside ASCE and SEI. Notably, the following are active structural standards development organizations, and the chairs of the related committees within the American Institute of Steel Construction (AISC), the American Concrete Institute (ACI), along with the ASCE 41 Committee are coordinating:

1. AISC is developing a specification that is to be a companion to ASCE 41. It will specify hysteretic relationships and capacities for steel components for use in PBD.

2. ACI is developing a similar specification for concrete structures. ACI also has developed a guideline document for performance-based design of new concrete building for earthquakes that specifies modeling parameters and acceptance criteria for concrete components used in new construction.

Outside of ASCE/SEI and with a scope that is broader than the SEI focus, many organizations are working or have developed documents that frame or discuss performance-based design aspects that are relevant with their organization's initiatives, including the following:

1. NIST Guideline for Community Resilience Planning for Buildings and Infrastructure Systems
2. International Code Council Performance Code
3. NFPA 5000 (sets performance goals)
4. NIBS Mulithazard Mitigation Council Performance Design papers

Other stakeholders outside of SEI standards, including AASHTO and the Eurocodes, participated in this task committee effort. While both organizations have had discussions of performance-based engineering, specific activities and outcomes have not been developed significantly at this time.

As SEI pursues this initiative, we must remain diligent to engage collaborators and stakeholders along the way.

## CHAPTER 4 – RECOMMENDATIONS TO THE BOARD OF GOVERNORS

The overview of the present state of practice, ongoing stakeholder outreach, and engagement activities within and beyond ASCE/SEI has led to the following recommendations to advance PBD within the structural engineering profession.

For the SEI Board of Governors, it is recommended that the overarching outcome and action be adopted:

- OUTCOME: Establish a sustained process to advance PBD within the engineering and construction industries.
- ACTION: Form a permanent Board-level committee to work with the SEI divisions (most likely CSAD, BPAD, and TAD), other Institutes within ASCE, and organizations outside ASCE to advance the profession toward PBD.

It is recommended that the proposed Board-level PBD committee provide oversight for the development of PBD standards for professional designers, with supporting materials for code adoption.

### 1. Establish SEI Board-Level Committee to Advance PBD Standards

The following five steps are proposed for establishing a Board-level PBD committee to support development of a unified SEI approach for the final desired PBD standards:

i. Identify steering committee
ii. Select Chairman and accept members that reflect committee scope and purpose
iii. Define a phased development plan and proposed coordination with other codes and standards, within and outside of SEI
iv. Develop an umbrella ASCE/SEI framework and guidance document for coordinated PBD activities within SEI and with other institutes.

## 2. Develop Outcomes and Activities for PBD Standards and Educational Materials

The Board-Level PBD committee should be charged with executing actions to achieve the ASCE/SEI vision for PBD through the desired outcomes. It should oversee the development of PBD guidance, standards and education materials through the outcomes and actions listed in Table 1. The outcomes and actions are categorized as short term (0-3 years), medium term (4-6 years), and long term (7+ years) activities and products. The general sequence of development is indicated in Table 1, though some areas or topics may be able to move toward standard development more quickly. There are many more short-term actions than medium and long-term actions listed in Table 1, but they do not all have to be started as short term actions. It is expected that other actions will emerge over time and that the actual sequencing will depend on the number of committees and members that are available to address the identified actions. The outcomes and action in Table 1 are briefly reviewed below.

### a. Develop Best Practice Guidelines for PBD

The first two outcomes (1 and 2) inform the process by evaluating current activities and guidance documents by ASCE/SEI, and other organizations, and by identifying relevant stakeholders that will need to be considered as products are developed[20]. An overview of available practices and tools, information and data, and research needs should include review of the following:

i. Current practice documents and case studies (PEER TBI, LATBSDC Tall Buildings Guidelines, ASCE 7-16 Chapters 1, 16 and Appendix E, ASCE 41, ICC Performance Codes, Other ASCE Institute documents, international documents)
ii. Current PBD committees within ASCE Institutes and their scope/purpose
iii. Existing resources such as the NIST Community Resilience Planning Guide for Buildings and Infrastructure Systems as a tool to define community resilience needs.
iv. Perspective of the stakeholder groups: Consumers (owners and their representatives, designers); Producers (manufacturers and their consultants); General public and Regulatory (Federal, state, and local agencies including building officials, commissions, etc.)

[20] Appendix E – Present State of Practice: Technical and Educational Challenges and Needs

Best Practice Guidelines for PBD topics are developed in the next set of outcomes (3 to 6) with activities to provide a sound technical basis for PBD methods and criteria[21,22,23,24]. The following topics should be included[25,26]:

v. Situations for pure PBD (e.g., ICCPC) and mixed PBD/prescriptive (e.g., ASCE 41)
vi. 'Deemed to comply' performance goals and solution methods in codes and standards
vii. Performance objectives based on target functionality for operation and during design events, and methodology for developing other performance goals (hazard independent)
viii. Scale of PBD – components, assemblies, structure, infrastructure system
ix. Criteria for selecting appropriate analytical methods, applications, etc. (hazard specific)

**b. Develop Pre-standard(s) for PBD**

Pre-standards should be developed from the Guidelines (Outcomes 7 and 8), where topics for designers are combined into a single document. The pre-standard for designers should target performance goals and objectives (all hazards), evaluation/design methods, and acceptance criteria for primary hazards.

**c. Develop Standard(s) for PBD**

Standards should be developed from the Pre-standard documents, with refinements and additions as needed. Draft code language for adoption of the standard in applicable codes should also be developed.

**d. Develop Educational Materials for PBD**

For broad dissemination, acceptance, and proper application, an education program should be developed that addresses the design professional, building code officials and peer reviewers, college students, and other key stakeholders.

**e. Develop Professional Qualifications for PBD**

Through SEI and the national reach of NCEES, address engineering qualifications for PBD, and implementation of testing standards for SE qualification that are needed to assure the public that those licensed to perform PBD are properly certified to do so.

## 3. Standards Development Process

[21] Appendix D - Resilience-Based Performance Standards for Buildings and Lifeline Systems
[22] Appendix I – Performance-Based Design of Non-building Structures
[23] Appendix J - Bridge Engineering and Performance-Based Design
[24] Appendix M – Performance-Based Requirements: Meaning, Limitations and Ways Forward
[25] Appendix O – Designing the Other 95%
[26] Appendix B – An Industry Conundrum: Ever Increasing Size and Complexity of Codes and Standards - A Contradiction to the Goals of Performance-Based Engineering?

For the development of Standards/Pre-standards for PBD a few common steps are required within the ASCE/SEI framework of standards development. These steps are found in the ASCE Rules for standards development and thus not repeated here; however one additional step is recommended to facilitate use of these PBD Standards in the design community. That additional step is to charge the standard chairs with the task of leading the adoption/inclusion of their PBD standard into the appropriate code, standard, or practice guideline.

**Table 1. Outcomes and Actions for Developing ASCE/SEI PBD Standards**

| Outcome | | Actions to Achieve Outcome | | |
|---|---|---|---|---|
| | | ***Short Term (0 – 3 years)*** | ***Medium Term (4 – 6 years)*** | ***Long Term (7+ years)*** |
| 1. | Report summarizing current PBD activities and efforts (within SEI and by other organizations). | Hold a summit of the leaders of the various PBD activities on-going within ASCE (or perhaps structural engineering in general) to discuss existing activities and associated goals, objectives and desired outcomes related to both community resilience and the resilience of individual buildings and lifeline systems. The goal of the summit is to identify gaps and overlaps and develop relationships for ongoing coordination among those groups. | | |
| 2. | Report summarizing key PBD needs of stakeholders, challenges, necessary collaborations, and obstacles. | Hold a summit (as envisioned by the Case for Change report, and led by the TAD committee charged to hold summits) with representatives of structural engineering and invited participants from other disciplines and professions impacted by the definition of performance goals and by transition to PBD. This summit will explore setting appropriate risk levels, the advantages and obstacles to advancement of PBD standards, and identify essential collaborators outside the structural engineering profession.<br><br>Develop a program and activities aimed at educating building officials owners, the insurance industry, and other construction industry participants (in addition to | | |

| Outcome | | Actions to Achieve Outcome | | |
|---|---|---|---|---|
| | | ***Short Term (0 – 3 years)*** | ***Medium Term (4 – 6 years)*** | ***Long Term (7+ years)*** |
| | | designers) on the benefits of PBD to them – articles in magazines, presentation at conferences, etc. | | |
| 3. | Prepare Best Practice Guidelines for Design Professionals on Building Structures, Non-structural Building Systems, and Non-building structures. | Develop methodology for specifying consistent performance goals and objectives that are supportive of community resilience planning. (for all hazards, methodology should be hazard independent).<br><br>Determine performance goals and objectives for specified design levels (e.g., Risk based performance levels of structures for consistency with (and transparency of) existing prescriptive codes and standards. Document in PBD Guidelines. | | |
| | | Develop example set of consistent performance goals/objectives for systems-level operational performance; identify gaps and inconsistencies. | | |
| 4. | Report documenting how to specify performance goals and objectives for a desired reliability and risk levels. | Identify standards for review and assessment.<br><br>Conduct critical assessment of structural performance between structural types, member vs system approaches, and reliability and risk for a given hazard (gravity, wind, EQ) and identify gaps and inconsistencies.<br><br>Develop a consistent basis of structural performance and reliability/risk for hazards and all ASCE | Promote removing ASD load combinations from all design codes/standards by improving LRFD methods for foundations and other systems that primarily rely on ASD. | |

| Outcome | | Actions to Achieve Outcome | | |
|---|---|---|---|---|
| | | ***Short Term (0 – 3 years)*** | ***Medium Term (4 – 6 years)*** | ***Long Term (7+ years)*** |
| | | design standards. (This should help promote resilient infrastructure as well.) | | |
| 5. | PBD Best Practice Guidelines for the peer review process. | Develop guidance for peer review process that includes assessment of performance goals/objectives, as well as engineering assumptions and analysis methods. (This document will benefit Building Officials, and designers, to further understand the PBD process.) | | |
| 6. | PBD Pre-Standards for Design Professionals on Building Structures, Non-structural Building Systems, and Non-building structures. | | Develop a consensus Pre-standard for Design Professionals that incorporates the Best Practice Guidance (Outcome 3) and Report on reliability and risk levels (Outcome 4). | |
| 7. | PBD Pre-Standards for the peer review process and Building Officials. | | Develop a consensus pre-standard for peer review process based on Outcome 5. | |
| 8. | PBD Standards for Design Professionals on Building Structures, Non-structural Building Systems, and Non-building structures. | | | Develop a consensus Standard for Design Professionals that incorporates the Best Practice Guidance (Outcome 6). |
| 9. | PBD Standards for the peer review process and Building Officials. | | | Develop a consensus Standard for peer review process (Outcome 7). |
| 10. | Educational materials to educate design professionals on PBD topics. | Develop educational materials for professional engineers on the thought process and perspectives that benefit/improve structural design for both prescriptive and PB designs. | Develop educational materials for engineering curriculums on the thought process and perspectives that benefit/improve structural design for both prescriptive and PB designs. | Update educational materials to reflect PBD Standards. |

| Outcome | | Actions to Achieve Outcome | | |
|---|---|---|---|---|
| | | ***Short Term (0 – 3 years)*** | ***Medium Term (4 – 6 years)*** | ***Long Term (7+ years)*** |
| | | Develop a Guided Online Course that introduces practitioners/building officials to performance-based design.<br><br>Partner with other major SDOs to develop additional Guided Online Courses that would couple performance objectives and prescriptive methods in codes. These could lead to certification.<br><br>Partner with universities to encourage/focus on fundamental design principles and concepts that include performance objectives. | Extend Guided Online Course to build a certificate program with more in-depth courses for various disciplines which other Institutes could develop. | |