Performance-Based Design is the Future

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We, as structural engineers, often find ourselves confined by a situation we created for ourselves. We operate in a design environment with easy access to information, have the ability to collect and analyze extensive data, and have access to robust and reliable analysis and design software. Nevertheless, prescriptive codes and standards we have developed prevent us from fully leveraging these capabilities. As we face multiple goals for our designs – safety, economy, serviceability, sustainability, and robustness – we can be constrained to follow a prescriptive path to a solution that often does not optimally satisfy any of them.

Although nearly all modern design specifications strive to achieve some level of performance, they do not establish specific performance levels. Rather, design conformance to prescriptive criteria on materials, configuration, detailing, strength, and stiffness is implicitly taken as evidence the desired performance will be achieved. We believe our structures are safe, but we rarely know the true safety margins or whether other design solutions would provide superior performance. To make matters worse, we rarely state, or even know, what performance levels we should strive to achieve.

As a result, we are not able to apply our full capabilities to the design process. We are evolving into masters of the Code, who add value by being able to navigate the complexity of prescriptive provisions rapidly, rather than by developing creative and innovative solutions to multi-faceted problems. The societies we serve are not getting maximum value from their limited resources of time, money, energy, and materials. Instead, they are getting designs that are constrained by prescriptive codes that attempt to address all conditions for all structures serving all purposes, with uncertain reliability because design by prescription neither quantifies nor directly evaluates performance.

Performance-based design is founded on the premise that structural systems must meet specific performance objectives. Specific performance expectations are set for the completed design, and processes are prescribed in minimal terms. Performance-based design, therefore, reverses the design process by defining the end goal as the starting point. The engineer then engages creativity and innovation employing science and principles of structural and material mechanics, unencumbered by unnecessary and in many cases counterproductive prescriptive requirements, to identify optimal solutions to multiple, and sometimes competing, objectives. The design is completed by demonstrating complying performance through analysis, simulation, testing, or a combination thereof.

Defined performance objectives are keys to the process because they establish the expectations for the design. The profession needs to describe for the public the damage levels or service states that are attainable for a variety of hazards acting at specific intensities on structures serving certain purposes and occupancies. For instance, engineering practice following performance-based approaches requires quantitative criteria such as 1) the structure should have less than a 10% chance of collapse given the occurrence of the Maximum Considered Earthquake and 2) no more than one wind event in 10 years should cause swaying troubling to occupants. Setting these performance goals and agreeing on them among the stakeholders will be challenging but critical to the process.

Performance-based design offers several advantages over prescriptive design. First, properly executed performance-based approaches enable desired performance to be attained with greater confidence and expectations of reliability mainly because of the focus on the damage states. Second, since the performance objectives for the design are explicitly defined, the stakeholders can select the expected performance levels that are appropriate and satisfy their own needs. Third, since performance is evaluated directly as part of the engineering process, engineers need not be limited by requirements to conform to prescriptive solutions, thereby allowing for innovation and creativity using new materials and systems, and using existing materials and systems in new ways.

Structural engineers will be able to declare the expected performance of individual building designs and demonstrate compliance by working with all stakeholders. Structural engineers will be able to innovate and develop designs that respond to needs for resilience, robustness, and sustainability. Performance-based design approaches in civil engineering will allow structural engineers to influence broader public debates, beyond the design of individual structures, to impact public safety, welfare, and resilience at the site, community, regional, and national levels. Structural engineers will advance their roles to become more informed and critical partners in the design team and the community.

While performance-based design processes are routine in many engineering disciplines, they are unfamiliar to most of the stakeholders in the construction industry. The process demands more of structural engineers, including a better understanding of risk assessment and management. Peer reviews likely will be vital to the validation process. However, performance-based engineering approaches encourage research and development, and innovative engineering processes. The result is the freedom to solve harder problems with better structures.

Performance-based design approaches are not needed for most structures. In the future, we could easily have dual code approaches for structural design. Design of routine structures could default to prescriptive requirements, with a performance-based option for those interested in exploring its benefits. However, performance-based design processes should become an accepted protocol for complicated, high-value, and mission-critical structures (e.g., hospitals, emergency facilities and shelters, high-rise and iconic buildings, etc.), since the communities they serve will benefit from the innovation and creativity performance-based approaches foster.

To understand more about performance-based design and to learn what the Structural Engineering Institute is pursuing to advance performance-based design, see the report from which this article is adapted: *Advocating for Performance-Based Design* (April 5, 2018, Task Committee Report to the Structural Engineering Institute Board of Governors, **https://goo.gl/XwiFBG**).▪

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