Prescriptive versus Performance-Based Design

by Dr. Timothy Mays, The Citadel

One of the most common complaints I hear from practicing engineers is, "Why are codes and standards thicker every time they are updated?" This question is usually followed with some suggestion that engineers these days are doing too much engineering and too much computer modeling in their design offices. My counterintuitive response to this question is that we are not doing too much engineering, but that we are actually doing less engineering, and the unfortunate impact this has on our graduates may be long lasting. The more voluminous codes and standards we see each update cycle are more associated with a paradigm shift away from designing structures using engineering theory to prescriptively detailing structures to meet assumed performance objectives developed by code committees.

Probably the most significant negative impact of prescriptive codes is that they can be misused by a litigious society. It is much easier for attorneys to prove that the engineer missed one prescriptive code provision than it is to show that the engineer did not appropriately address an "engineer shall consider" requirement explicitly. I can't speak for every engineer out there, but I can promise that I have reviewed my fair share of structural drawings developed by others over the last 20 years, and I can't recall any set of drawings without what some could label a "missed prescriptive requirement" of some sort. So, is performance-based design a step into the future or a revisiting of the past? A few examples may help answer this question.

The seismic design of piles that are part of flat slab bridge bents is a classic example. Flat slab bridges are one of the most common bridge types built in my home state of South Carolina, as well as in many other parts of the country. The bridge superstructure is supported on pile bents that resist lateral forces like a moment frame in the transverse direction and like a series of cantilevered columns in the longitudinal direction. Force-based methods presented in the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] allow the engineer to design the piles for forces that are reduced from their maximum expected value by a response modification factor (*R* factor). The *R* factor is based on the expected seismic performance of the piles. Spiral reinforcement quantity, spiral placement, and other pile details are then prescriptively determined based on the seismic zone designated for the structure by the AASHTO LRFD specifications. In other words, moment demand in the piles is calculated based on a fictitious reduction in seismic demand, and the spiral reinforcement quantity and layout are entirely prescriptive and are tied to confinement levels that the spiral is assumed to provide to the core concrete inside the spiral. This type of design and analysis is very easy to perform, but there is no guarantee regarding the performance of the structure. It is not true to say that this type of design is conservative because there is a real possibility that some of the required prescriptive details and analysis requirements could diminish, rather than improve, the seismic performance of the structure.

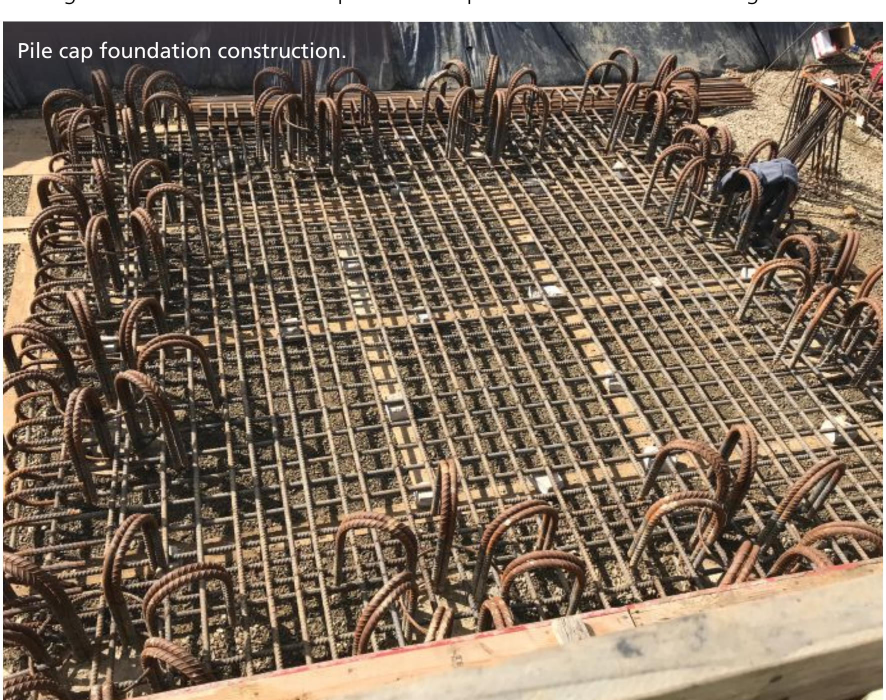
States such as California and South Carolina have developed their own performance-based design criteria for flat slab bridge structures. In these states, the engineer is required to more

Performance-based design and advanced modeling of bridges requires true engineering to determine structural details. This often leads to more economical designs that may perform even better than designs using a prescriptive approach.

accurately assess the performance of the piles using nonlinear pushover models to determine the maximum force that can be delivered to the system, the actual locations of seismic damage, and a more realistic estimate of overstrength requirements for the rest of the structure. The benefit to this advanced modeling is that true engineering is used to determine the pile details, including spiral reinforcement quantity and placement. When flat slab bridges are designed using both prescriptive design and performance-based design and the resulting structures are compared, the structure designed using performance-based design not only performs better but also may be more economical.

Pile cap design is another example. Many engineers do not realize that everything needed to check pile caps for shear in accordance with the AASHTO LRFD specifications is, well, not included in the AASHTO LRFD specifications. Many pile configurations used for bridge columns create shear demands for which the provisions of the AASHTO LRFD specifications are inappropriate. Is deep beam analysis appropriate for these cases? Maybe. Should finite element models be used? Possibly. Can the Concrete Reinforcing Steel Institute's *AASHTO Design Guide for Pile Caps*[2] (see the Fall 2018 issue of *ASPIRE*® for details of the contents of this guide) address all limit states? Hopefully. Fortunately, or unfortunately, to design pile caps, engineers need to engineer a solution. Engineers designing pile caps need to think through the limit states and provide additional conservatism where they feel uncomfortable with the load path or specific details. This is what some engineers have told me engineering was like "in the good old days."

After more than 20 years of teaching the design of reinforced concrete beams and columns at The Citadel, I can say that I spend more time helping students learn prescriptive detailing requirements at low Bloom's taxonomy assessment levels than I do teaching the higher-level applications of material modeling necessary to perform performance-based design of these elements. This means students are spending too much time memorizing rules and less time understanding the principles behind the topic, which would be much more valuable when they are required to think outside the box. Unfortunately, we have no choice but to teach this way because engineers are expected to adhere to all prescriptive requirements in the codes. If there is some good news, it might be that prescriptive requirements are most difficult to accept when they are expensive to build and when it can be shown that they are not really applicable to the subject structure. Fortunately, prescriptive requirements are much more of an issue for building codes than bridge codes and standards. Many bridge design specifications and state-specific design guidelines are already moving toward performance-based design.


Pile cap foundation construction.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications.* 9th ed. Washington, DC: AASHTO.
2. Concrete Reinforcing Steel Institute (CRSI). 2018. *AASHTO Design Guide for Pile Caps*. Schaumburg, IL: CRSI.