REVISI\nNG HIGH-\nPERFOR\nMANCE CONCRETE \nCLASSIFICATIONS

Henry G. Russell and H. Celik Ozyildirim initiated a thoughtful discussion (“Revising High-Performance Concrete Classifications,” August 2006, pp. 43-49) concerning the Federal Highway Administration’s definition and grades of high-performance concrete (HPC). The authors raise several important points and provide recommendations to help clarify existing performance characteristics used to define HPC used in highway structures.

The eight original performance characteristics, plus the three recommended by the authors, that characterize HPC for highway structures (freezing-and-thawing durability, scaling resistance, abrasion resistance, chloride penetration, alkali-silica reactivity, sulfate resistance, workability, compressive strength, modulus of elasticity, shrinkage, and creep) cover a wide range of characteristics designed to address either durability or structural performance needs. It has been our experience, however, that several of the factors traditionally considered to be structural design characteristics (compressive strength, modulus of elasticity, shrinkage, and creep) cover a wide range of characteristics designed to address either durability or structural performance needs. It has been our experience, however, that several of the factors traditionally considered to be structural design characteristics (compressive strength, modulus of elasticity, shrinkage, and creep, as identified in the article) also have a significant impact on durability because they affect the cracking tendencies of concrete. Thus, it can be argued that for some highway structures, particularly bridge decks, these “structural” characteristics should also be defined based on their effects on durability.

Concrete compressive strength is a good example of a typical “structural” characteristic that has a measurable impact on bridge deck durability. For monolithic bridge decks in Kansas, for instance, it has been observed that cracking increases by more than threefold as compressive strengths increase from just 31 to 45 MPa (4.5 to 6.5 ksi). 1 Thus, it is clear for bridge decks that a higher concrete strength may not always correspond to a higher level of durability. With continued emphasis on low-permeability concrete, low water-cementitious material ratios (w/cm) and the addition of mineral admixtures, such as silica fume, compressive strengths often easily exceed 45 MPa (6.5 ksi), contributing to possible durability problems. The key is to have a durable structure, not just high-quality concrete between the cracks.

Another example of a “structural” characteristic that has a significant effect on bridge deck durability is shrinkage—more specifically, early-age shrinkage 2 that occurs before the concrete has a chance to creep. For this reason, specifying the shrinkage performance grade based on 30 days, for example, instead of 180 days is an attractive alternative that will decrease construction delays (noted by the authors) and may be a better performance indicator than the 180-day values.

In addition to material characteristics, construction techniques and environmental conditions also have a significant influence on concrete durability. Most of these factors are addressed in construction specifications, and when possible, should also be reflected in the material performance criteria. For example, drying shrinkage, in part, depends on the length of the curing period. While some studies have indicated that the curing period has little effect on shrinkage, 3 our studies 4 have consistently demonstrated (for a wide range of mixture proportions and blends of cementitious materials and for curing periods ranging from 1 to 28 days) that concrete shrinks less when cured longer. Curing all specimens for 28 days (as specified by ASTM C 157) does not take into consideration the actual curing period specified for highway structures. Where applicable, specimens used to determine the shrinkage performance grade should be cured for the same length of time as the structure in question. This would, at least in part, couple the performance grade with the curing regime and help to emphasize the importance of good curing practices.

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References

Authors’ response
The authors thank the University of Kansas team for their comments
and appreciate their contribution toward identifying factors that influence bridge deck cracking. In developing the revised criteria, we stayed within the original concept that a standard ASTM or AASHTO test exists for each characteristic, exceptions to the standard methods would be minimized, and that performance levels can be established for each characteristic.

Our focus with the structural characteristics was for long-span bridge applications where shrinkage and creep have a major effect on long-term deformations and prestress losses. The reviewers raise a valid point about the crossover between the characteristics that were termed “structural” and their influence on bridge deck cracking and durability. If we apply the structural characteristics to the bridge deck cracking issue, then we need to have low compressive strength, low modulus of elasticity, low shrinkage, and high creep. Only shrinkage would fall into the high-performance concrete characteristics as defined in the article. The others might be considered low-performance concrete because they are readily achievable.

The desire to produce low-permeability concrete has led to deck concretes having higher compressive strengths, with associated higher modulus of elasticity and lower creep, than really needed for structural performance. Maybe the time has come to specify maximum as well as minimum values for concrete compressive strength and the w/cm for concrete bridge decks. In Virginia, the w/cm for bridge deck concretes range from 0.40 to 0.45, while achieving low permeabilities. Concrete with lower ratios is harder to place and cure and is more prone to cracking.

The ASTM C 157 test for shrinkage provides a means to compare different unreinforced concretes under a standard curing regime. The test, like other standard tests, does not truly represent what happens to concrete in a real structure. In addition to the 28-day curing time mentioned by the reviewers, the initial length is measured at a concrete age of 24 hours. This misses any dimensional changes that take place within the first 24 hours.

However, there is no reason why a standard test method cannot be modified for a specific application such as bridge decks.

In summary, we agree that there are relationships between the different structural and durability performance characteristics. The important issue is to be aware of these characteristics and select them according to the needs of a particular project.

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