Current Trends with Expanded Shale Clay and Slate Lightweight Aggregate

By William H. Wolfe

For over 90 years, expanded shale clay and slate lightweight aggregates (LWA) have been used as a component of building materials primarily for density reduction and the corresponding benefits. However, recently there has been a trend to utilize the unique properties of LWA in innovative ways that improve the durability and service life of traditional concrete.

Internal Curing

Civil and structural engineers continually strive to produce pavements and structures that are more durable and have longer service lives. We have seen bridges progress from wooden structures to steel and concrete structures, yet many bridge decks still last less then 25 years. In an effort to improve these structures, today's high performance concretes (HPC) commonly use supplemental cementious materials (SCM) that improve the sustainability and reduce the permeability of the concrete. The reduced permeability is designed to keep chlorides from penetrating the concrete and reaching the reinforcing; however, one of the major challenges with HPC is shrinkage. Shrinkage causes stresses to develop within the concrete and if they get high enough, the concrete cracks, first as micro cracks and, then as visible cracks. Cracking develops pathways for water and chlorides to permeate into the concrete, reducing the durability of the structure.

Recently a great deal of research has been conducted on reducing the cracking in concrete and especially HPC. One development of this research is to utilize prewetted LWA to cure the concrete from the inside out, commonly referred to as internal curing (IC). Today's HPC does a great job of reducing the permeability as long as the concrete doesn't crack, but it usually does. Unfortunately, the reduction in permeability of HPC also reduces the amount of externally applied curing water that reaches the interior of the concrete. IC helps fill this gap by providing the additional curing water where and when it is needed. Since the IC water is not released from the pores of the LWA until after the cement uses up the available mix water, the additional IC water does not affect the w/cm.

Bridge Decks

Several bridge decks have utilized IC where typically 30 to 40% of the normal weight fines are replaced with an equal volume of prewetted LWA. The LWA will slightly reduce the concrete density and modulus of elasticity, but has no effect on the concrete's workability or finishability. In fact, several contractors prefer the internally cured concrete mixture. Slight increases in compressive strength have been seen due to an increase in the amount of cement hydrated and SCM reaction.

Case Study – Internal Curing

In the fall of 2009, the Court Street Bridge over Interstate 81 in Syracuse, NY was constructed with internally cured normal weight concrete. The Spencer and Butternut Street bridges were constructed at the same time without IC, and offered a great comparison. The mix designs were identical with the exception of the prewetted fine lightweight aggregate used for IC. The concretes were produced at the same ready mix plant and were placed by the same contractor three weeks apart. Test results showed the IC mixture had over 10% higher compressive strengths at 28 days.

Concrete Designed for Reduced Cracking

Lightweight concrete is also specified because of its tendency to crack less. The reduced cracking can be linked to several properties found at the interfacial transition zone (ITZ) where the aggregate meets the cementitious paste. The superior ITZ found with expanded shale, clay, and slate (ESCS) lightweight concrete can be attributed to several unique characteristics.

- The surface of ESCS lightweight aggregates is pozzolanic in nature. The alumina/silicate surface combines with the lime (calcium hydroxide, $CaOH_2$) liberated by the hydration of the Portland cement, forming a stronger bond between aggregate and cement paste.
- The elastic similarities between the ESCS particle and the cementitious matrix reduce microcracking. The similar moduli of elasticity prevent stress concentrations from forming at the ITZ.
- Water equilibrium is achieved between the porous LWA and the porous cementitious matrix. In normal weight concrete, bleed water can form around these non-absorbent aggregates which will drive up the water cement ratio in the ITZ.

Weaknesses and flaws developed in the ITZ can lead to increased permeability when they link up with microcracking in the cementitious matrix. In severe climates, where winter applications of deicing salt are common, this can lead to increased penetration of aggressive agents that accelerate the corrosion of reinforcing steel and deteriorate the concrete.

Case Study – Reduced Cracking Tendency

In 2010, the New York State Department of Transportation opened up its first overhead Single Point Urban Interchange (SPUI). The bridge design was unique in that it was wider than it was long and thereby created cracking concerns. The solution was to design the deck with lightweight concrete, not for its reduced weight properties but for its reduced tendency to crack. The concrete design was less than 110 lb/ft^3 and utilized flyash and silica fume to reduce concrete permeability.

Conclusion

These innovative uses of lightweight aggregate can increase the percentages of supplemental cementious materials, which increases the sustainability of concretes. Reduced cracking tendency in lightweight concrete, as well as internally cured normal weight concrete, will help to increase the service lives of structures and pavements and help to protect our country's infrastructure.▪

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