0-6681: Optimizing Concrete Pavement Type Selection Based on Aggregate

Background

Design concept and structural responses of jointed plain concrete pavement (CPCD) and continuously reinforced concrete pavement (CRCP) are quite different. In CPCD, concrete volume changes are allowed to a full extent, and accommodations are made to ensure good load transfer at discontinuities, i.e., transverse contraction joints. On the other hand, concrete volume changes are restrained to a significant degree in CRCP by longitudinal reinforcement and base friction. Because of this vastly different behavior between the two pavement types, concrete with a high coefficient of thermal expansion (CoTE) is not an ideal material for CRCP. In other words, the performance of CRCP with a high-CoTE concrete will be compromised, with a high probability of severe spalling. In accordance with the Texas Department of Transportation (TxDOT) Guidelines for Selection of Concrete Pavement Type developed in 2000, most of the rigid pavement constructed since that time is CRCP, and very limited lane miles of CPCD have been built. Severe spalling occurred in CRCP built with a high-CoTE concrete. This functional distress type cannot be prevented by conservative structural designs of rigid pavement. The distress is related to concrete materials and should be addressed accordingly. The repair of CRCP distresses is difficult, expensive, and time consuming, and its performance has not always been good. The best practice is to prevent distresses in CRCP.

What the Researchers Did

Researchers identified sections with severe spalling and/or delamination distresses as well as no distresses in CRCP. Cores were taken from those sections and evaluated for CoTE and modulus of elasticity. Coarse aggregate sources that were known to cause severe spalling and/or delamination distresses were identified. Coarse aggregates were obtained from those sources, and extensive laboratory evaluations were conducted. Life-cycle cost analysis was also conducted to develop a methodology for the selection of an optimum rigid pavement type based on coarse aggregate availability. Detailed information on the aggregate costs at quarries and transportation costs was obtained and an elaborate analysis was conducted. A test section was built to develop best construction practices for joint saw cutting. Saw cuts were made at various ages of concrete, from two hours up to 24 hours, and damage to the concrete was evaluated.

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What They Found

The findings from the laboratory and life-cycle cost evaluations of rigid pavements can be summarized as follows:

- Excellent correlation was observed between functional distresses in CRCP (severe spalling) and the CoTE of concrete. CRCP sections where concrete had a CoTE above 5.5 microstrain per °F exhibited severe spalling. On the other hand, CRCP sections with a CoTE less than 5.5 microstrain per °F did not have spalling problems.
- Extensive laboratory evaluations of concrete with various coarse aggregate types revealed the following:
    - All 10 aggregate scores qualified according to TxDOT construction specification Item 421, Hydraulic Cement Concrete, requirements.
    - Three sources failed to meet the Ministry of Ontario's (MTO's) unconfined freezing and thawing requirement, and one source did not meet MTO's Micro-Deval (MD) requirement. When combining unconfined freezing and thawing results and MD results, four sources did not qualify.
    - All the concrete mixes satisfied the Class P concrete strength requirements according to Item 360, Concrete Pavement.
    - River gravel showed the highest 28-day modulus of elasticity. Aggregate with higher absorption showed a lower 28-day modulus of elasticity.
    - Slate showed the highest CoTE, and igneous rock had the lowest CoTE. River gravel showed higher CoTE than the river gravel and limestone blend, justifying the potential of reducing concrete CoTE by blending low-CoTE aggregate with high-CoTE aggregate.
- The cost of the coarse aggregate per ton did not have a large effect on the overall initial construction cost of the pavement.
- CRCP costs more initially because of the large amount of steel that must be placed into it, but that is fairly balanced by the low associated maintenance costs.
- The performance of CPCD with a high-CoTE concrete could be comparable to that of CRCP if sound construction practices are employed.

What This Means

It is a poor practice to use concrete with a high CoTE in CRCP. Concrete with a high CoTE, more specifically a value greater than 5.5 microstrain per °F, should not be used in CRCP; rather, it should be used in CPCD. Even though the Guidelines for Selection of Concrete Pavement Type developed in 2000 (which stipulates that when rigid pavement is selected for a project, only CRCP should be used) is still in effect at TxDOT, a new guideline needs to be developed to address the distresses that occur in CRCP when concrete with a high CoTE is used. By considering the concrete material property as affected by coarse aggregate type and the availability of local coarse aggregate, an optimum rigid pavement type can be selected for a project, which will result in a lower life-cycle cost while improving pavement performance.

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