NEW YORK PUTS INDUSTRIAL BY-PRODUCTS BACK TO WORK

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

The most common distress for bridge decks in New York State has been spalling from the corrosion of reinforcing steel when moisture and de-icing salt penetrate the concrete. The rate of penetration depends on the permeability of the concrete. In 1994 the New York State Department of Transportation created the Bridge Deck Task Force to focus on design, materials, and construction aspects of this problem. The task force determined that significant improvements in service life and quality would result from a mixture that produces concrete with reduced permeability and decreased potential for cracking.

PROBLEM

The task force's objectives in addressing corrosion-induced spalling and deterioration of bridge decks included the following: conduct a literature search and laboratory trials to find options for a workable concrete mixture; and produce concrete that is more durable, less subject to cracking, and less permeable than concrete produced from mixtures currently specified by NYSDOT. The task force also sought to ensure that the new mixture would comply with the existing specifications.

SOLUTION

The literature review indicated that many states are seeking to lower the permeability of concrete for bridge decks. The use of pozzolans and low water-to-cement ratio are two methods for achieving low permeability with pozzolans the more effective. Research in other states has shown that reducing the water-to-cement ratio and providing proper cure will result in an increase in the ultimate compressive strength of concrete, and a decrease in cracking related to shrinkage. Other experience indicates that Class F fly ash, silica fume, and ground granulated blast-furnace slag have the potential for enhancing the effects of low water-to-cement ratios. NYSDOT has had positive experiences with separate use of Class F fly ash and silica fume, but none in combining these pozzolans. Whereas other states have had positive experiences with slag mixtures, New York's experience is limited.

On the basis of the literature review, NYSDOT conducted laboratory tests. Commonly used materials and methods were used to achieve a workable mixture that promised decreased permeability and reduced cracking potential. Three trial mixtures and one NYSDOT standard concrete mixture (Class H) were tested in the laboratory. All four samples had constituents from the same sources to ensure valid comparison. In addition, a modified silica fume—concrete mixture from a local producer was tested. Design parameters for all mixtures are shown in Table 1. Each laboratory trial mixture had a low water-to-cement ratio, contained Class F fly ash and silica fume as a portion of the total cementitious content, and used normal-range, set-retarding, water-reducing admixtures. All of the concrete mixtures were evaluated in the laboratory for handling and workability, strength gain, permeability, resistance to cracking, and scaling.

All of the trial mixtures performed better than the standard mix (Table 1). The test results indicated the optimum mixture design to be Class "HP" (high performance). On the basis of limited data, the Class HP mixture had better handling and workability characteristics than the standard mix and produced concrete that developed strengths greater than the minimum required. The new mix showed a 70 percent reduction in permeability, 96 percent reduction in cracking, and no significant scaling. These promising findings prompted a field trial.

In 1994 the Class HP concrete was placed on Route 78 in Erie County, New York. The mixture was easily placed and finished. Its measured strength was better than the strengths achieved in the laboratory. The permeability was 50 percent lower than that of the laboratory samples, a significant improvement. No cracking or scaling was observed during visual inspection 18 months after construction.

The results of the laboratory and field trials led

Suggestions for "Rescarch Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418 (telephone 202-334-2952; e-mail gjayapra@nas.cdu).

NEW YORK STATE DOT

Route 78 in Erie County, New York, was site of first application of low-permeable concrete made with Class F fly ash and silica fume.

NYSDOT to place 6503 square meters (7,778 square yards) of concrete for 11 bridge decks using Class HP concrete in the 1995 construction season without any problems. Preliminary results show all of the field-trial decks performing satisfactorily. NYSDOT will specify Class HP concrete as the standard for future bridge-deck designs.

BENEFIT

NYSDOT research confirms the findings of other states that pozzolans are effective in lowering the permeability of concrete, which greatly improves the durability of the bridge decks. The use of industrial by-products such as Class F fly ash and silica fume helps to conserve resources and energy.

Individual bid prices for Class HP concrete on the 1995 projects ranged from 25 percent less to 35 percent more than Class H bid prices, with an overall 10 percent increase in the in-place cost of materials. These price variations depended on geographic location and the capabilities of local concrete producers. As with any new specifications, NYSDOT expects the average bid price to decrease as contractors become familiar with Class HP use.

The initial cost increases will be offset by the expected extension of service life. The expected service life of a bridge deck made with Class H concrete is 50 years. Computer modeling indicates that a bridge deck made with Class HP concrete will have an expected service life of at least twice as long as that of Class H concrete.

Assuming a weighted average bid price of $18.07 for the 0.12 million square meters (1.3 million square feet) of deck placed each year by NYSDOT, the 1995 cost would have been $23.5 million for Class H concrete. For Class HP, using a conservative estimate of double the life expec-tancy of Class H concrete and subtracting the average 10 percent cost increase, the expected lifecycle cost could save NYSDOT $8.9 million per year. There is also potential for recycling 1000 metric tons (1,100 tons) of fly ash each year.

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TABLE 1
High-Performance Concrete Laboratory Mix Design and Testing Results

MATERIAL	NYSDOT CLASS H (CONTROL)	NYSDOT CLASS HP (MOD. CLASS H)	NYSDOT MODIFIED CLASS E	IMPROVED AGGREGATE-PACKING MIX	NYSDOT MODIFIED MICROSILICA[a]
WATER (kg/m^3)	167.2	160.1	153.6	149.4	153.0
WATER:CEMENTITIOUS RATIO	0.40	0.40	0.40	0.40	0.36
CEMENT (kg/m^3)	400.3	296.5	289.4	278.7	343.4
FLY ASH (kg/m^3)	0	80.1	71.2	71.2	46.3
MICROSILICA (kg/m^3)	0	23.7	23.7	23.7	35.6
FINE AGGREGATE (kg/m^3)	690.8	680.2	622.7	786.9	664.2
COARSE AGGREGATE[b] (kg/m^3)	1038.9	1038.3	1134.4	980.8	1022.9
28 DAY COMPRESSIVE STRENGTH (MPa)	42.4 42.4	43.7 44.1	47.1 46.0	48.5 46.5	32.5 36.2
28 DAY RAPID CHLORIDE PERMEABILITY (Coulombs)	4349 4339	1291 1249	1293 1227	1667 1752	894 875 978
CRACKING[c] - Measured length (m)	1.150	0.025	0.250	0.350	—
CRACKING[d] - Length/ Area (m/m^2)	5.800	0.130	1.260	1.770	—

[a] Concrete mix used on another project from which samples were taken for testing, no slab specimens cast.
[b] Laboratory mixes used a coarse aggregate split of 50-percent No. 1 stone and 50-percent No. 2 stone.
[c] No cracking formed at 4 1/2 hr as concrete had not set, Cracking reported is from measurements taken at 24 hr, no further cracking developed.
[d] Bridge decks measured for cracking in the field average approximately 3000 mm/m^2 (98.75 in./yd^2).