CUTTING COSTS WITH RESEARCH, TECHNICAL ASSISTANCE, AND SPECIAL SERVICES

NEW YORK STATE TRANSPORTATION RESEARCH AND DEVELOPMENT BUREAU

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The payoffs of research conducted by the Transportation Research and Development Bureau of the New York State Department of Transportation are not limited to study findings that suggest feasible solutions to a variety of design, construction, and maintenance problems. Benefits also derive from the bureau's provision of technical assistance and special services to clients throughout NYSDOT. Bureau staff render technical assistance in the form of advice, support, and instrumentation that help clients to define and solve problems of modest scope or short duration. Special services include technology transfer, through which the bureau uses the results of research (conducted by NYSDOT and other organizations) to improve the quality or cost-effectiveness of operations and products, and library operations, through which the bureau gives clients access to technical literature and diverse information services. The bureau also provides a team of professional statisticians who advise the department on research methodology, experiment design, and data analysis. In all these activities, considerable interaction occurs between researchers and clients, providing the mutual benefits of greater knowledge and appreciation of each other's roles and responsibilities.

The research community must not hesitate to demonstrate and call attention to the benefits of its work, for appreciation of the research function is often a major determinant of the level of its continuation within an organization. Three examples of the bureau's applied research, technical assistance, and special services reveal just how significant these benefits can be.

APPLIED RESEARCH: NEW PAVEMENT DESIGN PROCEDURE

For most of this century, NYSDOT used a purely empirical procedure to design highway pavements. About 20 years ago, this procedure was formally incorporated into the department's *Pavement Design Manual*, providing a simplified system for selecting pavement thickness on the basis of highway classification, the hourly traffic volume for which the highway was designed, and two truck-weight categories: heavy and light. Most state and interstate rigid pavements in the 1950s and 1960s were built using this procedure, which specified 225-millimeter (9-inch) thick slabs, joint spacings from 18 to 30 meters (60 to 100 feet), and steel-mesh reinforcement. For flexible pavements, the department used asphaltic top, binder, and base courses, with total thicknesses ranging from 100 to 265 millimeters (4 to 10½ inches). All rigid and flexible pavements had 300-millimeter (12-inch), dense-graded subbase courses (Figure 1).

As long as traffic patterns continued as they had in the past, this procedure served design needs reasonably well. But after passage of the Surface Transportation Assistance Act of 1982, legal load limits and vehicle sizes progressively increased, and changing truck volumes, sizes, and weights could no longer be ignored. By 1987 it had become clear that the design manual's "Pavement Selection Guide" had to be updated to deal with current and future traffic conditions.

The need for stronger, more durable pavements led the Transportation Research and Development Bureau to develop a new thickness-design method.

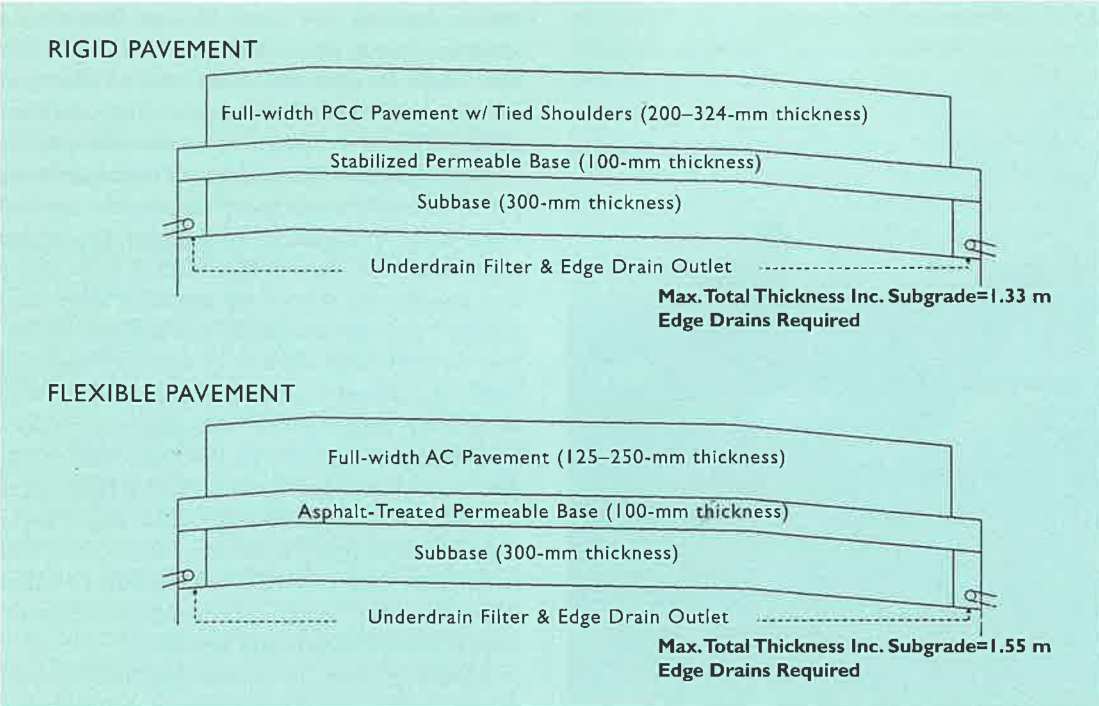

FIGURE 1 Typical pavement cross sections (not drawn to scale).

Working from the American Association of State Highway and Transportation Officials' 1986 *Pavement Design Guide* and the 1993 revisions to the guide, a special pavement-design task force developed the *Thickness Design Manual for New and Reconstructed Pavements*, published in 1993. The specifications detailed in the manual are being applied statewide to both reconstructed and new highway pavements with more than 1.6 kilometers (1 mile) of continuous centerline. The AASHTO design equations and variables have been calibrated to both environmental conditions in New York and the past performance of the state's highway pavements.

The new design addresses problems in both rigid and flexible pavements. In rigid pavements, cracking is reduced by thicker, shorter slabs and wider truck lanes, and faulting is minimized by dowels of greater diameter, a 100-millimeter (4-inch) treated permeable base with edge drains, and full-depth concrete shoulders tied to adjoining travel lanes. In high-volume flexible pavements, environment-related distress is expected to be reduced, making load-related distress the main mode of pavement failure. In both rigid and flexible pavements, granular subgrades should minimize frost-related problems, and a new subsurface drainage system should eliminate drainage-induced distress.

NYSDOT first used the new design in construction of the Corning Bypass, a 4.5-kilometer (2.8-mile) four-lane divided highway with jointed rigid pavement, around the city of Corning. The bypass features a 225-millimeter (9-inch) pavement thickness; tied full-depth-concrete shoulders; a 100-millimeter (4-inch) stabilized permeable base; a 300-millimeter (12-inch) dense-graded subbase; and a subsurface drainage system, including continuous 100-millimeter (4-inch) diameter perforated-plastic edge drains with non-slotted outlets every 76 meters (250 feet).

The department conducted a life-cycle cost analysis to evaluate the overall effectiveness of the new design, assuming a 64-year service life, periodic maintenance and rehabilitation, an hourly cost of $15 to users in terms of delays, and a 4-percent discount rate. According to the analysis, the life-cycle costs of high-volume roads (175,000 annual average daily traffic) constructed with the new design would be 60 percent lower than those of roads built with the old design.

Technical Assistance: Improved Shear-Keys

The bureau's structures research group provides technical assistance to the department through experimental and analytical research and development of bridges and other structures. One of the group's primary goals is increasing the cost-effectiveness of highway facilities. One of its successes was improving the performance of bridge decks resting on adjoining precast box-beams.

Asphalt paver is used to place a stabilized permeable base on Corning Bypass, the first project to incorporate specifications from New York State Department of Transportation's pavement-thickness design manual updated in 1993.

Adjacent-precast-beam bridges have become increasingly popular because they can be built more quickly than other kinds of bridges, resulting in lower construction costs, and because they provide greater vertical clearance. Before 1992 the department built such bridges by connecting precast beams with grouted shear keys designed to transfer shear force from one beam to another. No transverse tendons were used for spans up to 15 meters (50 feet), but one tendon was used at midspan for spans of 15 to 23 meters (50 to 75 feet), and tendons were used at outer quarter-points for longer spans. Shear keys were cast on-site, and a concrete overlay of a 150-millimeter (6-inch) or greater thickness reinforced with welded-wire fabric was poured. The overlay was composite with stirrups rising from the beams into the deck.

Field inspectors often observed longitudinal cracks in overlays above shear keys soon after construction was completed. Transverse cracking, propagating outward from these longitudinal cracks, was also observed in older or heavily traveled precast box-beam bridges. In addition, premature spalling and water leakage through the shear-key joints were noted. In 1992 NYSDOT's Structures Design and Construction Division asked researchers to investigate the severity of these problems and identify possible solutions.

With assistance from the rest of the department, the structures research group developed a detailed work plan, which included defining the bridge population to be studied, the extent of field inspection needed, the format for reporting inspection findings, and the criteria for performance evaluation. In 1991, with the help of regional inspection staffs, researchers coordinated a statewide, comprehensive inspection of 186 adjacent-precast-beam bridges built between 1985 and 1990. It was discovered that more than one-half of the bridges had longitudinal cracks over shear keys. These cracks were mapped on superstructure plans. The researchers then collected information on other states' shear-key construction practices and interviewed some of their bridge inspectors.

Review of both the survey data and state-of-the-art practices resulted in several recommendations for improvements. In 1992 the Structures Design and Construction Division adopted two of these recommendations: increasing shear-key size to almost the full depth of precast beams, and increasing the number of transverse post-tensioning tendons to 3 for spans of less than 15 meters (50 feet) and to 5 for longer spans. The new full-depth shear-keys/transverse-ties system was expected to reduce deck longitudinal cracking by making the entire transverse section behave more like a single unit, thereby effectively transferring shear force.

Since implementation of the recommended changes, spot checks have indicated less cracking. A follow-up study of 89 bridges with the new full-depth shear-key/transverse-tie system was initiated in 1996 to evaluate bridge performance and identify any possible further improvements. Preliminary analysis of information compiled by regional inspectors indicates significant improvement in shear-key performance. Only 24 percent of the new bridges show evidence of shear-key-related cracking compared with 54 percent of the 186 bridges constructed with the earlier design. Longitudinal cracking per bridge and associated leakage have also been reduced.

The marked decrease in large-scale repair work and premature deck replacement is estimated to amount to an annual cost savings of about $3 million. The research leading to this improvement cost about $80,000 (not including the minimal additional construction costs associated with the new shear-key system), yielding a benefit-cost ratio of about 100 during a 3-year period. Further potential improvements, such as increased reinforcement of deck overlays, full-width bearing pads under beams, and improved design of the transverse post-tensioning system, could increase cost savings.

Special Services: Statistical Methods

New York recently adopted a new concrete mix, designated Class HP (high performance), for bridge decks (see "Research Pays Off," *TR News* May–June 1996). A modification of NYSDOT's standard bridge-deck concrete, this mix provides better handling characteristics, reduces permeability and increases resistance to cracking (thus reducing exposure of deck reinforcement and substructure to de-icing chemicals), and displays little or no surface scaling. It also promises more than twice the previously expected concrete service life, with 5-year benefits potentially exceeding $40 million. The mix, 20 percent of which is fly ash and 6 percent microsilica, is now the required concrete mix for all bridge decks in New York.

To create an even better concrete mix, the bureau's statisticians designed a highly efficient experiment to investigate the effects on cracking and permeability of various combinations of microsilica, fly-ash, and cementitious materials. Because reduced permeability is considered to be the most important variable in increasing the durability of the new concrete mixes, the bureau's goal was to optimize this property by varying the amounts of cementitious materials while keeping other variables constant. On the basis of a literature review and analysis of available data, the statisticians recommended varying the total weight of cementitious materials within the range of 357 to 428 kilograms per cubic meter (600 to 720 pounds per cubic foot), percentages of fly ash from 10 to 30, and percentages of microsilica from 4 to 16. Within these ranges, they chose five total weights of cementitious materials, five percentages of fly ash, and five percentages of microsilica with which to experiment. But not all 125 resulting combinations of the three materials had to be tested. A three-factor central composite mix design meant that researchers could investigate the properties of these combinations by actually making only 15 of them.

The most promising of the 15 mixes contained 15 percent fly ash, 12 percent microsilica, and a total weight of cementitious materials of 375 kilograms per cubic meter (630 pounds per cubic foot). This mix demonstrated the lowest permeability and the greatest resistance to cracking and scaling. The permeability and cracking and scaling resistance of this mix appeared to be unaffected by small changes in amounts of mix components. Lack of sensitivity to such changes is highly desirable because small deviations from laboratory procedures during the preparation of a concrete mix can significantly affect mix properties, and such deviations always occur in the field. These preliminary findings must be confirmed in further studies and rigorous field tests, but the bureau has already concluded that careful statistical planning of experiments to determine the optimal concrete mix should be pursued in the future.

Importance of Research and Related Activities

The projects described above are yielding significant benefits. As noted, the new pavement-thickness design is expected to reduce the life-cycle costs of roads built in the future by 60 percent. The full-depth shear-keys/transverse-ties system for bridges has resulted in a marked decrease in large-scale repair work and premature deck replacement for an estimated annual cost savings of about $3 million. And careful statistical planning greatly increased the efficiency of an experiment to determine an optimal concrete mix for bridge decks, saving time and money.

In the struggle to keep pace with ever greater demands on transportation systems, research efforts may be given a low priority. However, as the bureau's projects demonstrate, investments in research and related activities, such as technical assistance and special services, are likely to increase the cost-effectiveness of design, maintenance, and construction projects.