Partnering for Performance—Iowa's Experience with Design and Construction Enhancements for Quality Improvement of Concrete Pavements

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A strong and proven working relationship among the Iowa Department of Transportation, Iowa's counties and cities, and the Iowa Concrete Paving Association is focused on meeting owners' needs by improving quality of workmanship, product, and innovative techniques. Partnering, a new paradigm for owner and contractor relations that emphasizes up-front team building, clear definition of common objectives, synchronized customs for rapid issue resolution, and joint evaluation of partnership effectiveness, is a popular objective of the 1990s. Construction partnering has existed in a limited form for years, but such relationships have found some difficulty of survival in a system in which the low bidder wins the contract, the taxpayer dollar is at stake, and the government may be sensitive to criticism of not spending the money wisely. Today, new partnering concepts to protect the public interest have been developed by contracting authority and contractor alliances with both parties. Most partnering has been between a contracting authority and contractor with mutual intent to construct a specific project. A more general partnership among the Iowa Department of Transportation, other Iowa contracting authorities, and the Iowa Concrete Paving Association is described. In 1992, Iowa contracting agencies and the concrete paving industry began an Iowa initiative for continuing quality improvement of concrete pavements. Through the Iowa partnership, changes have been made in standard designs, specifications, materials use, and construction techniques to enhance concrete pavement quality.

Over the past several years, much has been written about the evolution of partnering in the field of public highway construction. One definition for partnering describes a new paradigm of owner and contractor relations with emphasis on up-front team building, clear definition of common objectives, synchronized customs for rapid issue resolution, and joint evaluation of partnership effectiveness (*1*). Construction partnering has existed to a limited extent throughout the years, but has found some difficulty of survival in a system in which the low bidder wins the contract, the taxpayer dollar is at stake, and the government may be sensitive to criticism of not spending the money wisely. In the past, there has been a tendency for adverse relationships between the contractor and contracting authority, which some managers thought was beneficial to the owner (*2*).

Today, contracting authorities and industry have become more aware of the total costs of infrastructure and recognize the need to maximize the benefit derived from all administrative and construction dollars spent. It is now necessary to protect the public interest by contracting authority and contractor alliances, with both parties cooperating to achieve different but complementary objectives.

A strong, proven working relationship has developed among the Iowa Department of Transportation (Iowa DOT), Iowa's counties and cities, and the Iowa Concrete Paving Association over many years. This relationship is focused on meeting the owners' needs through quality of workmanship, product, and innovative techniques. In the 1990s, as partners committed to continuing quality improvement of concrete pavements, the construction industry is encouraged to consider changes in design, specifications, and construction procedures that enhance pavement performance.

HISTORICAL BACKGROUND

In 1904, the Iowa legislature passed two laws that have established the responsibility for roadway design, construction, and maintenance in the state. The Iowa State Highway Commission was established, and the supervisors of each county were required to employ a competent engineer to supervise the building of permanent roads. Over the years, legislation has further defined these responsibilities, provided for funding of the roadway network, and broadened the scope to intermodal transportation. The Iowa State Highway Commission became the Iowa Department of Transportation in 1974.

During the early 1900s, Iowa's first concrete city street was built in LeMars, Iowa. It was the second concrete street built in America. The first rural county concrete pavement was constructed near Eddyville, Iowa, in 1911 and from 1913 to 1919 the seedling miles of Iowa's primary highway system were paved with concrete.

A $100 million road bond issue was passed in 1928 to finance the construction of 10,304 km (6,400 mi) of concrete roads connecting main market centers statewide. These major commitments to road building by Iowa contracting agencies and the Iowa concrete paving industry established the foundation for a relationship that would grow through the years (*3*).

The Iowa partnership was highlighted in the late 1940s when a farm-to-market road bill provided major funding for road improvements in the 99 counties. Shortly thereafter, J. Johnson, an Iowa State Highway Commission employee, invented the slipform paving machine. Recognizing the significance of Johnson's machine and responding to the need for an economical method of constructing concrete pavements, Iowa contractors Perkins and Dale refined the Johnson machine and introduced the Quad City

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Formless Paver by 1954 (*4*). The slipform paver modernized the industry and allowed concrete to sustain its prominence as an economical, high-performance pavement choice for construction of Iowa's state and county roads and city streets.

The Iowa Concrete Paving Association (ICPA) was founded in 1963 by six Iowa contractors as an organization that would help Iowa agencies design and plan roads and promote the use of concrete, advancing its use in the construction of highways, streets, airfields, and other public improvements. These objectives would be accomplished through product performance, high standards of workmanship, education, research, and innovation.

Today, ICPA's 26 contractor members and 80 allied associates work with Iowa's contracting authorities to provide permanent pavements that serve the public interest.

IOWA PARTNERSHIP

The Iowa partnership for quality and performance has developed through years of cooperation in establishing and reaching mutual goals. Since ICPA's inception, association members and key Iowa DOT staff have gathered annually to review specifications and design standards that may be of concern relative to cost, benefit, and impact on pavement performance. The annual concrete paving workshop in Iowa provides the nation's largest local forum where more than 500 engineers, contractors, and owners gather to explore methods for improving concrete pavement performance through advanced design, materials use, construction techniques, and innovative technology. For 30 years, Iowa contractors, field personnel, agency engineers, and inspectors have been recognized for their outstanding workmanship by a joint ICPA-Iowa DOT awards program at the workshop. Through these traditions of Iowa's partnership, the local contracting agencies and concrete paving industry are recognized as national leaders in the development and implementation of quality enhancements and concrete solutions.

From the slipform development in 1949 to work on high-tech concrete mixes today, many changes in design, materials, and construction techniques have influenced local and national concrete paving technology while improving pavement quality and performance.

The Iowa concrete pavement has evolved over years of experience and varying conditions of service. The agencies have specified jointed reinforced concrete pavement, continuous reinforced concrete pavements, and jointed concrete pavements. Jointed concrete pavement is the preferred design from the specifying agency's and the contractor's perspectives. Jointed concrete pavements without dowels are standard for Iowa's low-volume roads. On the basis of field experience, the design for higher-volume pavements has progressed from no dowels to doweled transverse joints with dowels placed on 30.48-cm (12-in.) centers at 6.10-m (20-ft) intervals (*5*).

Working together, agency and industry personnel have developed standards for keyway spacing and bar size that afford the best constructibility and uniformity of application. Originally, longitudinal tiebar spacing ranged from 30.48 cm (12 in.) to 76.20 cm (30 in.), depending on the width and the thickness of the pavement. After an annual specification meeting, changes were made so that 38.25-cm (15-in.) and 76.20-cm (30-in.) tiebar spacing is standard for keyway in longitudinal joints. The number of bar sizes has been reduced to assist in contractor and supplier inventory control and to minimize confusion in the field.

Joint spacing and dimension standards have been improved to simplify field operations and provide the desired performance. Sealants have been tested to determine the optimum selection for each pavement service level. Today, hot-poured sealants are specified for local, Surface Transportation Program, and primary National Highway System (NHS) pavements. A preformed elastomeric compression seal is specified for transverse joints on interstate pavements.

The Iowa design for four-lane NHS pavements now specifies a widened, 4.27 m (14 ft) outside lane that maximizes pavement performance potential through proven structural advantage. The widened lane is comparable to a tied portland cement concrete paved shoulder, but more economical and easier for the contractor to build.

In 1995, Iowa NHS pavement designs will specify a subbase that extends 0.92 m (3 ft) beyond the edge of the slab. Previous 0.61-m (2-ft) wide padlines did not take full advantage of today's slipform technology. The added subbase width allows for full support of newer paving machine's tracks.

Iowa's first variation of concrete recycling was showcased in 1976 when a composite portland cement concrete and asphalt pavement was recycled. The recycled aggregate was used in the concrete base course of a two-course concrete pavement (*6*). In 1977, concrete pavement was recycled for aggregate in new pavement on projects in Page and Pottawattamie counties (*7*). Although successful, the technique has not been used extensively because many reconstruction candidates were originally built with D-cracking coarse aggregates.

Greene County, Iowa, has used recycled concrete for aggregate in concrete pavement reconstruction on 30.59 km (19 mi) of low-volume roadway constructed since 1985 (*8*). The original Greene County pavements were built using high-durability river aggregates.

With limited funds for reconstruction of an aging Interstate system whose traffic had far exceeded design projections, Iowa began to construct mainline inlays of its Interstate highways in 1979 while maintaining the existing shoulder base. Several changes have improved inlay design and construction. One of the first inlays was constructed one-lane wide with traffic adjacent to the construction zone. Construction difficulties and risk to workers led to construction of two lanes simultaneously with traffic shifted to the other side of the Interstate in a head-to-head configuration. Today, the inside shoulder is completely reconstructed to accommodate construction operations. More than 483 km (300 mi) of two-lane Interstates (I–80, I–35, and I–29) have been reconstructed as concrete inlays and refinements over the past 15 years have provided a constructible, high-performance pavement.

Since 1982, Iowa contractors have recycled existing Interstate pavement as a drainable base course placed before inlay construction. The crushed material provides a drainage layer with a permeability rating of approximately 305 m (1,000 ft) per day. A change in maximum allowable particle size from 12.7 cm (¾ in.) to 5.63 cm (1½ in.) has improved crushing efficiency and material use without compromising the drainage characteristics of the material.

Before 1993, the existing concrete was broken, removed, and hauled to sites near the project, and then crushed, graded, and hauled back to the grade for placement. In 1993 on an I–80 inlay project in central Iowa, the Iowa DOT allowed ICPA contractor Manatt's Inc. to introduce the paradigm system. The innovative recycling system integrated a mobile train of on-grade equipment for breaking, removing, crushing, and placing of the recycled

material. The paradigm reduces the cost of site transportation and processing and eliminates potential safety hazards inherent to off-site hauling. Typical problems of trench construction were also reduced when the recycled material was replaced immediately on the subgrade behind the crushing train (*9*).

Iowa has maintained a role of national leadership in developing concrete solutions for pavement rehabilitation. Concrete overlays are now widely accepted statewide as a rehabilitation alternative. Although Iowa built its first bonded overlay on U.S. 34 in Des Moines County in 1955 (*10*), the modern development of bonded overlay technology began with projects constructed in 1976 on a state highway and two city streets in Waterloo. Today, more than 104.65 km (65 mi) of bonded concrete overlay have been constructed in Iowa on Interstate and primary highways, county roads, city streets, and airport runways and taxiways (*11*). These projects have provided opportunities for research and development in the use of grout for bonding, steel and polypropylene fibers, crack replication, and crack reinforcement.

In 1994, bonded overlays with Fast Track concrete paving were further refined when the Iowa DOT and ICPA contractor Cedar Valley Corporation rehabilitated an existing concrete pavement on Iowa Highway 3 in north central Iowa. Special conditions of this project required traffic to be maintained during the paving operation and returned to all lanes at night. This necessitated half-width paving with a concrete mix that provided center point flexural strength of 2,411.50 kPa (350 psi) in six hr or less. Research on the project includes maturity and pulse velocity testing, bond and temperature relationships, and evaluation of bond when grout is or is not required.

Unbonded overlays soon followed the development of bonded overlays. Experience with stress relief and bond breaker courses constructed with sand seals, slurry seals, and thin asphalt overlays now allows the engineer to design for the condition of the existing roadway. Design guidelines for joints have also been developed from experience, and continued evaluation considers varying thickness designs for performance. Working together, Iowa contractors and contracting authorities have refined unbonded overlay technology and rehabilitated 276.92 km (172 mi) of county roads and airport runways and taxiways (*12*).

Developed as a concrete solution to the ever increasing and recurrent costs of maintaining existing asphalt county roads, whitetopping has become an excellent method for rehabilitating more than 508.76 km (316 mi) of Iowa's county roads and airport runways and taxiways (*13*). The industry and agencies have developed standards for preparing the existing asphalt surface, jointing, and thickness design. An ultra-thin whitetopping research project in Louisville, Kentucky, has confirmed that 5.08-cm (2-in.) and 7.65-cm (3-in.) overlays will carry a significant number of axle loads (*14*). In addition, an Iowa research project in Dallas County suggests that there may be a structural composite action in whitetopping that would support performance of previously unheard of ultra-thin designs (*15*).

Iowa DOT, FHWA, and concrete paving industry worked together in 1994 to design and construct an 11.27-km (7-mi) long paving project that will provide the opportunity to evaluate thin concrete overlays on asphalt. The project is funded in part by moneys allocated in the Intermodal Surface Transportation Efficiency Act of 1992 (Section 6005). Plans called for 65 test sections that consider alternative methods for preparing an existing asphalt surface, using a combination of various concrete thicknesses, plain and fiber reinforced concrete, varying joint spacings, and a typical asphalt overlay.

In response to Iowa's need to complete certain reconstruction or rehabilitation projects in a timely manner while minimizing traffic interruptions, the industry and agencies have worked together since 1986 to develop Fast Track concrete paving. The first major Fast Track project was a bonded overlay and widening project constructed on U.S. 71 in Buena Vista County in 1986 (*16*). In 1988, a major urban highway in Cedar Rapids, Iowa, was constructed with Fast Track II mixes that included a 6-hr concrete maturity for intersections constructed at night and restored to service by 6:00 a.m. (*17*). More than 35 Fast Track projects have been constructed in the state.

Concrete mixes are now designed to meet the demands of the owner or user. Projects, such as the previously mentioned Iowa Highway 3 bonded overlay, provide opportunities to cooperatively evaluate design, materials, and construction techniques that will improve this popular rehabilitation technique.

After considerable discussion between the industry and contracting agencies, Iowa authorities began to offer a smoothness incentive by specification in 1990. Recently, the threshold for incentive was revised from 30.48 cm/1.61 km (12 in./mi) to 17.78 cm/1.61 km (7 in./mi) on the California profilograph (*18*). This change confirms that, despite the contracting industry's initial resistance to a smoothness requirement, the quality of Iowa concrete pavements has improved significantly since the specification's implementation. Incentives provide an opportunity for the better contractors to benefit from their expertise and encourage average contractors to improve their operations to remain competitive. The benefit for the contracting authority is estimated to outweigh the associated cost of incentives.

In 1988, Iowa DOT began to offer incentive payments for pavements constructed in excess of the design thickness, recognizing that thicker concrete enhances expected long-term pavement performance. Before that time, contractors were paid the contract price for design thickness and penalized for short cores. The current statistically based specification rewards the contractor for thickness and uniformity, allowing a maximum achievable incentive at 105 percent of the contract price. Positive response from the contractors indicates that incentives encourage construction of better quality pavement.

SUSTAINING THE IOWA PARTNERSHIP

All good partnerships need to be revitalized periodically with a renewed focus. In 1991, at ICPA's annual business meeting, the Iowa DOT Highway Division Director and Chief Engineer challenged Iowa's concrete paving industry to reach for a higher level of concrete pavement quality. Although the Iowa partnership continues to work, industry may have become complacent in pursuit of old objectives that were not applicable to new demands from the traveling public (the highway user).

In October 1992, ICPA and Iowa DOT entered into a new partnership for Continuing Quality Improvement (CQI). A Quality Advisory Committee was established to (a) identify issues of concern relevant to pavement quality and performance, (b) appoint working groups to study the issues and offer recommendations, and (c) direct the implementation of quality enhancements. In the tradition of quality management, the advisory committee was formed from the owner and top-management levels of the agency and industry. Three contractor and owners; the ICPA Executive Vice President; the Iowa DOT Construction, Materials, and Design

Engineers; and the Deputy Division Administrator for FHWA serve on the advisory committee.

Paramount to the activity of the advisory committee was an immediate understanding that recommendations from the committee would be brought to the appropriate Iowa DOT authorities and the contracting industry for consideration of action.

Among the early objectives established was an intent to consider pavement performance characteristics and the impact that design, specifications, and construction techniques have on quality of the constructed pavement. Four task forces were appointed to address specific quality concerns. Members of the task forces were selected from a broad cross section of contractor and agency personnel at management and field levels of administration, design, materials, and construction. People offering the highest expertise in each subject area were chosen to serve, including experts from other parts of the country. The four task forces have focused on pavement smoothness, paver operations, quality of materials, and concrete mixes. The advisory committee outlined specific objectives for each task force.

The Pavement Smoothness Task Force quickly acknowledged that pavement smoothness was important to pavement performance and the public's perception of pavement quality. In 1994, a revised statistical smoothness specification was implemented for all applicable projects. This specification will be reviewed in the future to evaluate its impact on contractor incentive achievement, performance-related quality, and perceived quality for rural and urban pavements.

One recommendation from the task force has resulted in the revision of a road standard to allow a day's work joint at any location in a pavement panel as long as it is no closer than 1.52 m (5 ft) from a proposed contraction or doweled contraction joint. Another recommendation extends the pavement subbase 1.91 m (3 ft) beyond the edge of pavement to enhance pavement constructibility.

On the basis of discussions of the task force, contracting authorities are asked to set 7.62-m (25-ft) hubs for grade control and contractors are asked to set 4.37-m (12.5-ft) stakes when the rate of change of curve exceeds 2 percent. Contractors also reduce profilograph traces with 0.51-cm (0.2-in.) and 0.0-cm (0-in.) blanking band to evaluate correlation to perceived riding quality. In addition, the ride-related effects of cutting or not cutting wire ties on contraction/dowel (CD) baskets are being reviewed.

Finally, the Pavement Smoothness Task Force supported the construction of a 1993 Iowa pavement research test to evaluate how texture spacing, depth, and direction affect smoothness, skid resistance, and noise in and out of the vehicle.

The Paver Operations Task Force has studied edge slump control, accurate tie bar placement, and consistent and proper concrete consolidation through vibration. The active involvement of several equipment manufacturing representatives and field supervisors familiar with equipment operation was important to the success of the group.

The task force concluded that many edge slump control problems are related to poor communication at the field level. No one told the builder and the inspector why edge control was important. A similar lack of communication was found to be the primary cause for misplaced tie bars. These concerns were referred to the advisory committee for discussion at the annual field training seminar. It is encouraging that, after communicating with the field personnel, the incidence of misplaced tie bars was isolated to two projects in 1993, down from seven in 1992.

Excessive and inconsistent concrete consolidation may have contributed to premature pavement deterioration on isolated projects constructed in Iowa during the past 10 years. Therefore, the Paver Operations Task Force studied the lessons of vibrator frequency, vibrator placement, and mix workability. Guidelines have been developed for vibration and are being revised as more is learned about the effect of vibration on consolidation in slipform paving operations. Communications and transfer of responsibility at the field level should be improved to ensure proper consolidation. The task force has therefore developed field checklists that consistently remind the equipment operators and field management personnel of their obligation to build a high-quality pavement.

One of the primary issues supporting a new initiative for continuing quality improvement was a mutual concern about a recent concrete paving project that exhibited early deterioration. Some type of expansive failure, not unlike alkali silica reaction (ASR), has occurred on a limited number of projects in Iowa. The industry and Iowa DOT considered it essential to identify the cause and act to prevent future occurrences. It was thus quickly agreed that a Materials Quality Task Force would be appointed to review investigations previously conducted by Iowa DOT and further consider issues relative to quality of material and pavement performance.

With information gained from two outside investigations and further in-house research, Iowa DOT concluded that the root cause of the unusual deterioration was not ASR. Additional study is in progress to consider delayed ettringite crystalline growth in the concrete and the integrity of the concrete at time of construction.

As the research continues, the task force has concurred with the Iowa DOT actions that set limits for combined alkali of cementitious material, require use of Type II cement, and direct closer monitoring of air content after placing and finishing. The Materials Quality Task Force is also working with the Concrete Mix Task Force to explore relationships of concrete workability, consolidation, and durability.

The Quality Advisory Committee appointed a Concrete Mix Task Force to study whether the standard Iowa recipe mixes provide an optimum mix for strength, performance, and economy. The task force was directed to explore alternative approaches to mix design. The task force has considered how to improve the quality of mixes economically, discussed the characteristics that truly measure concrete quality, and studied optimization of mixes by using combined aggregate gradations (Shilstone and SHRP Packing Diagram methods). The task force is also involved in projects that will field test the effects of various aggregate gradations; cement contents; and their combined impact on concrete strength, durability, and workability.

The Concrete Mix Task Force has begun exploring parameters for the eventual consideration of a performance-related specification (PRS) for concrete and concrete pavements. This objective responds to a directive from the Quality Advisory Committee to begin transition toward PRS with a goal to be on line in 3 years.

Throughout the CQI endeavor, it has been apparent that communication from top management and engineering to the field needs to be improved to enhance quality of the constructed project. Working with the Quality Advisory Committee, the four task forces have helped create an agenda of quality issues that was discussed at an annual construction season startup seminar for field personnel. Learning from the success of a seminar on joints and joint sealing offered under the cosponsorship of Iowa DOT and ICPA in April 1992, additional seminars addressing concrete pavement quality were offered in 1993 and 1994. Attendance has exceeded 150 at all

meetings, and the support from agencies and contractors has maintained a balance for useful interaction. The seminars will likely be continued.

In 1995, the Quality Advisory Committee will consider interactive cable television as a seminar delivery system, maximizing attendance and minimizing cost.

FUTURE OBJECTIVES

In October 1993, the Quality Advisory Committee renewed its commitment to the quality initiative by participating in a 1-day field tour of Iowa concrete paving projects, new and old. The tour included representatives from the industry and agency and a staff engineer from the American Concrete Pavement Association. The opportunity to share ideas and rekindle a common interest is important to CQJ initiative. An annual event of this nature is anticipated.

Following that field tour, a half-day meeting was held to reflect on the tour and establish direction for the coming year. The challenge to consider and move toward a PRS was a result of that meeting. Over the winter, two meetings were held to focus specifically on PRS issues. FHWA's Office of Technology Applications assisted in this orientation, and the Quality Advisory Committee has now begun to assign tasks relevant to PRS to new working groups. The first PRS group commissioned is a Non-Destructive Testing Task Force.

Another new task force has been assigned to consider constructibility issues relative to urban pavements. The group convened in fall 1994 to focus on specific construction projects.

In other meetings during 1994, the Quality Advisory Committee evaluated the progress and objectives of the four original task force groups. All groups will continue to pursue objectives with the exception of the Paver Operations Task Force, which has completed its assigned tasks. It is not the intent that these groups continue to work for extended terms. By limiting the tasks, it is hoped that the momentum of the quality initiative may be enhanced. This also allows participation by a broad cross section of the combined industry. County engineers, city engineers, and consultants will soon be included on the task forces to ensure that all levels of the governmental and engineering communities are included in the quest for quality improvement.

CONCLUSIONS

Iowa's partnership between contracting agencies and the concrete paving industry is working for continuing quality improvement of pavement design and construction. The cooperative relationship has enabled a strong focus for quality enhancement and expanding technology. The Iowa experience has established improved pavement designs; encouraged development of new approaches to recycling, reconstruction, and resurfacing; initiated development of Fast Track paving, and has confirmed agency and industry commitment to the development of a new generation of performance-related specifications. By using incentives, the PRS will elevate the quality of concrete pavements without detriment to the competitive bid process.

The Iowa initiative for continuing quality improvement has been judged beneficial to the contracting agency and the concrete paving industry. More than 60 individuals representing all facets of the combined industry now meet regularly to work for quality and a more permanent pavement. State and local contracting authorities and the concrete paving industry are committed to the success of the cooperative partnership in Iowa and recommend a similar program to any other contracting agency or industry truly interested in quality improvement of design construction and concrete pavement performance.

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