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HIGHWAY QUALITY COMPENDIUM

JANUARY 2007

U.S. Department of Transportation
Federal Highway Administration

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Archived

Table of Contents

Archived

Archived

Foreword

By James B. Sorenson

Better, faster, safer, and more cost-effective. For highway practitioners across the country, highway quality is all about achieving the shared goal of building, preserving, and maintaining better roadways. As we move further into the 21st century, State transportation agencies, the Federal Highway Administration (FHWA), highway contractors, and others in the transportation sector are faced with a number of significant challenges. Traffic growth and increased congestion, freight management, national security, and an ever-increasing sensitivity to the environment are all driving forces for future highway improvements. Along with these challenges, transportation agencies must also contend with limited budgets and shrinking workforces, and an aging transportation system with an increasing percentage of the infrastructure in need of significant repair. Because of these factors, a strong focus on quality is more important than ever. All of these issues will require significant attention to improving quality and ensuring that we get the highest performance possible from our future highway projects.

Quality is not a single definition or a one-step process, but rather encompasses everything from project planning and design to construction materials, workmanship, and durability of the finished product. Safety characteristics, project management, and financial stewardship are all critical concerns. An attention to quality in all aspects of a highway project is important to producing a final product that safely and efficiently meets the long-term needs of communities and delivers value for taxpayer dollars. We see quality in a highway that conforms to certain design or construction standards while providing excellent long-term performance. The public sees quality in congestion relief, increased mobility, and safety benefits. Quality is not one characteristic but an end result that provides value to all.

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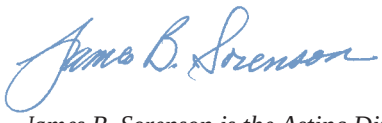
The articles in this compendium reflect the broad range of quality characteristics that add up to a successful highway construction program and satisfied customers, providing a snapshot of where we are today and where we are headed in the future. Whether it be new technologies, innovative work techniques, well-trained and motivated employees, or accelerated construction schedules that ease driver inconvenience, these quality practices are making a difference in many areas across the country. As this compendium illustrates, they are also moving us forward as we seek to meet and exceed our customers' expectations, obtain the best system performance for the dollar amounts invested, and sustain the public trust.

With the increased demands on today's highway agencies, continuous quality improvements are essential for a successful highway program. Meeting our quality goals ultimately depends on each of us.



James B. Sorenson is the Acting Director of FHWA's Office of Asset Management.

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BUILDING QUALITY INTO HIGHWAYS

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New NHI Course Presents Strategies for Managing Construction Workmanship

The many factors involved in constructing and inspecting a highway project to ensure the desired quality of the finished product, including legal liability, risk, and quality assurance issues, are the focus of a new 2-day course now available from the Federal Highway Administration's (FHWA) National Highway Institute (NHI). Using real-life examples, "Managing Construction Workmanship" (Course No. FHWA-NHI-134055) looks at approaches that will help improve the quality of field decisions, with the goal of enhancing overall product quality and improving long-term system performance.

"With States facing serious attrition among their inspection forces, it's crucial to bring up new inspectors among the ranks to give them the confidence and skills they need to do the job to the best of their ability," says Christopher Newman of FHWA's Office of Asset Management. "While there is little substitute for on-the-job experience, this course educates field personnel in regard to the roles and responsibilities of inspectors, the acceptance of materials and what constitutes proper workmanship, and the concepts and factors involved in risk and engineering analysis."

On completion of the course, participants will be able to:

(1) Identify the components of workmanship as they relate to highway and bridge construction and assess their own inspection skills.

(2) Describe the construction team (owners, engineers, contractors, suppliers, and inspectors) and the roles of each team member in achieving good communication and quality workmanship.

(3) Link different types of specifications to the associated roles and responsibilities of the inspector, contractor, engineer, and owner.

NHI's new course on "Managing Construction Workmanship" covers the many factors involved in constructing and inspecting a highway project, including legal liability, risk, and quality assurance issues.

(4) Identify situations in which legal issues related to inspection and inspector duties affect the performance of their assignments.

(5) Apply the basic concepts of risk assessment to case studies from construction inspections.

Participants will also learn about various successful State training and certification programs that lead to improved construction workmanship

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and quality, as well as how to locate training and certification programs in their own jurisdictions.

"The course allows participants to understand the nature of construction inspection as well as the expectations of both the department of transportation inspection staff and the contractor's staff in completing a quality construction project," says Bill Beuter of the Virginia Department of Transportation, which hosted the course in Thornburg, Virginia, in October 2005. "The course is very powerful in that it allows discussions about what constitutes a quality project."

"The course allows participants to understand the nature of construction inspection as well as the expectations of both the department of transportation inspection staff and the contractor's staff in completing a quality construction project."

The course is designed for field personnel, from engineers to technicians, who are involved in all aspects of highway construction. "The ideal audience for the course will have a mix of experience and responsibility levels so that agency-specific practices can be shared by more experienced participants with those who are newer to the field," says Newman. Course materials are also appropriate for project managers or resident engineers. The cost of the course is $270 per participant, with a minimum class size of 20 and a maximum of 30. Participants can earn 1.2 continuing education units.

For more information on the course content, contact Christopher Newman at FHWA, 202-366-2023 (email: christopher.newman@fhwa.dot.gov). To schedule the course, contact your local FHWA division office or the NHI Training Team at 703-235-0534 (email: nhitraining@fhwa.dot.gov), or visit the NHI Web site at www.nhi.fhwa.dot.gov.

Reprinted from *Focus,* July 2006.

Archived

Highways for LIFE

Changing the Way Today's Infrastructure Is Built

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It's a new way of doing business. Just as the construction of the Interstate Highway System transformed the way America traveled over the past 50 years, the Federal Highway Administration's (FHWA) new Highways for LIFE program aims to bring a higher level of innovation and technology to improving the Nation's roadways.

At a time when congestion is on the rise, highways and structures are aging and requiring increased rehabilitation and reconstruction, and road work can bring months or years of delays, Highways for LIFE is about achieving the Long lasting, Innovative, and Fast construction of Efficient and safe highway infrastructure. Its goals are to:

- Improve safety
- Reduce congestion due to construction
- Improve quality.

"We want to get things done better, faster, safer, and cheaper," says Kathleen Bergeron of FHWA's Highways for LIFE team. "The key to that is creating a culture within the highway community that invites innovation and rapidly adopts new practices, as well as effective technology transfer and improved ways for getting new technology to State highway agencies and practitioners faster."

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) provides $75 million in funding for Highways for LIFE–$15 million for fiscal year (FY) 2006 and $20 million per year for FY 2007-2009. The program includes demonstration construction projects, stakeholder input and involvement, technology transfer, technology partnerships, information dissemination, and monitoring and evaluation.

A transportation department can apply for Highways for LIFE funding for a highway project if the project constructs, reconstructs, or rehabilitates a route or connection on an eligible Federal-aid highway and uses innovative technologies, manufacturing processes, financing, or contracting methods that meet performance goals for safety, congestion, and quality. The amount allocated for a Highways for LIFE project may be up to 20 percent, but not more than $5 million, of the total project cost. The Federal share for projects approved under this program may be up to 100 percent.

The program's technology partnerships will provide incentive funding for the adaptation of proven innovations from outside the U.S. highway community, so that the innovations are ready for use. Technology transfer initiatives will market innovations to highway practitioners and managers, introduce and deliver ready to use innovations to the highway community, and provide training and technical assistance. Information dissemination efforts will provide information to States, industry, the public, and FHWA about Highways for LIFE, project success stories, and innovations. Stakeholder input and involvement strategies will also inform States, industry, and highway users about Highways for LIFE and offer mechanisms to solicit feedback on the implementation of the program. Through monitoring and evaluation, Highways for LIFE will gather information on all of the program elements to improve the performance of the elements, document the benefits, and explain the expenditures.

The innovative technologies that the Highways for LIFE program is promoting include prefabricated bridge elements and systems, road safety audits, and tools and techniques for "Making Work Zones Work Better." Prefabricated bridge elements and systems, ranging from substructures to entire bridges, can be manufactured offsite, under controlled conditions, and brought to the job site ready to install (see December 2004 *Focus*). Using these prefabricated systems reduces the traffic congestion and environmental impacts of bridge construction projects and improves work zone safety for both workers and drivers. Other advantages can include

At a 2004 media event held at the construction site of the new Woodrow Wilson Bridge outside Washington, DC, U.S. Transportation Secretary Norman Y. Mineta highlighted Highways for LIFE's goals of achieving the long lasting, innovative, and fast construction of efficient and safe highway infrastructure.

improved constructibility, increased quality, and lower costs. More information on best practices for prefabricated bridge elements and systems and details on how these systems are being used around the country are available online at www.fhwa.dot.gov/bridge/prefab.

A road safety audit (RSA) is a formal safety performance examination of an existing or planned road or intersection by an independent audit team. The RSA team assesses the crash potential and safety performance of the roadway or intersection and then prepares a report identifying potential safety issues. Project managers can then evaluate the project plans and determine appropriate changes that need to be made. Additional information on RSA is available at safety.fhwa.dot.gov/state_program/rsa.

FHWA's "Making Work Zones Work Better" outreach campaign is designed to provide transportation practitioners with tools, best practices, and innovative technologies to reduce congestion and accidents in work zones. These tools and technologies include the *Work Zones Best Practices Guidebook*, fact sheets and case studies on State activities to improve mobility and safety in work zones, and the QuickZone 2.0 software, which is being used by highway agencies and contractors as a work zone delay impact analysis tool (see April 2005 *Focus*). For more information on "Making Work Zones Work Better" and the many resources available, visit ops.fhwa.dot.gov/wz.

The Highways for LIFE Web site (www.fhwa.dot.gov/hfl) features a toolbox of information on innovative technologies, success stories, information contacts, and other resources. A Highways for LIFE workshop on Innovation and a technical session on Performance Goals will also be held at the January 2006 Transportation Research Board Annual Meeting in Washington, DC. For more information on Highways for LIFE, contact Byron Lord at FHWA, 202-366-1325 (fax: 202-366-3943; email: byron.lord@fhwa.dot.gov). *Focus* will also continue to provide updates as Highways for LIFE implementation activities and workshops are developed.

Reprinted from *Focus,* September 2005.

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Dispelling Highway Construction Myths

by Peter Kopac

Examining a few commonly believed half-truths may help materials, structural, and pavements engineers develop sound and effective quality assurance programs.

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Sometimes when people hear or read an idea often enough, it becomes accepted as fact and ingrained as a self-evident truth. Invariably, these notions are passed on to others, and soon no one questions them any more. "Man was not meant to fly" was accepted as fact for centuries. But because a few people did not accept that belief, they developed an important means of transportation.

Part art and part science, the discipline of quality assurance for highway construction abounds with half-truths, myths, and misconceptions. These myths typically originate from well-meaning sources. Some myths serve a worthy function by simplifying the difficult to make it more understandable. However, on the negative side, myths:

- May be partly true, but not all of the time, so they can lead to an incomplete understanding of important concepts
- Encourage decisionmaking as a seat-of-the-pants approach rather than one based on facts and data
- Leave a narrow, rigid impression that stifles creativity

For quality assurance to keep progressing, highway agencies and contractors might examine several key myths that have become firmly entrenched as truth. Dispelling the more persistent myths that have gained a strong foothold can help engineers develop a better understanding of the concepts and principles needed to produce and implement sound and effective quality assurance specifications and programs.

Myth No. 1—You Can't Inspect Quality Into the Product

This assertion is often made to reinforce the viewpoint that only the highway contractor can build quality into the product. This myth contends that it is too late for the agency to improve quality once the contractor's product has been submitted for acceptance.

This is true under only one scenario, that in which the contractor's product must be accepted as is, with a pay decrease being the agency's sole recourse for deficient quality. Typically, that is not the case in highway construction.

During construction, it is a daily occurrence for agency inspectors to reject truckloads of portland cement or asphalt concrete. Although it does not happen too often, the contractor is required to remove and replace entire lots exhibiting very low quality. In some cases, inspections can lead to inplace correcting and reworking of unacceptable product. Some examples are pavement surface grinding to improve smoothness, scarification (loosening) and addition of material to increase base course thickness, and removal and replacement of segregated or honeycombed areas to improve durability and appearance.

One way to measure the effectiveness of a construction acceptance plan is by how much quality has improved as a result of inspection. This measure of the effectiveness of an acceptance plan is based on the assumption that a person can inspect quality into the product. Practitioners of highway construction quality assurance generally have overlooked this measure. It calls for determining the difference or ratio between the average incoming quality submitted by the contractor and the average outgoing quality after inspection and rectification.

Some acceptance plans are designed to control or optimize the average outgoing quality. These plans depend on an initial sampling inspection to estimate the number of defectives in a lot. When the number is high, 100-percent inspection is conducted. Any accepted lot is improved by the elimination or correction of defectives found during the inspection.

Such acceptance plans have been applied mostly in industrial situations, but they have the potential for various applications during highway construction. To control the average outgoing quality, either the highway agency or the contractor can use the acceptance plan to inspect such items as masonry units, reinforcement bars, dowel bars, guardrail, right-of-way fence—indeed any product delivered in bulk.

Myth No. 2—The Ultimate Goal Is Product Performance

Agencies often present this performance argument in support of warranty specifications that hold the contractor responsible for a specified level of pavement performance, as opposed to a specified level of materials and construction quality. The argument maintains that although quality and performance go together and are both important, performance should be specified because it is the agency's ultimate goal.

But is it really? Striving for high pavement performance without sufficient regard for the cost to achieve that performance level is not in keeping with the best interests of the road user. Ideally, an agency's goal should be neither maximizing quality nor maximizing performance, but instead should consider minimizing life cycle costs (including user costs due to crashes, delays, noise, and so forth).

Although most developers of warranty specifications consider costs in establishing performance thresholds, the established thresholds may not be at the optimum values to also minimize life cycle costs. This issue can be addressed by developing warranty specifications that seek to minimize life cycle costs. Another approach would be for an agency to directly specify the life cycle costs desired.

To assist agencies, the Federal Highway Administration (FHWA) developed guidance for performance-related specifications that focus on minimizing life cycle costs. The guide specifications are based on pavement performance models that convert various levels of construction quality into estimated life cycle costs. The standard way for an agency to apply these specifications is to specify the desired construction quality level and hence the desired postconstruction life cycle cost of the pavement. The paving contractor can obtain a pay increase by providing a quality level that results in a lower-than-specified postconstruction estimate of life cycle cost.

Another more innovative way to apply these specifications might be for each potential paving contractor to submit a target life cycle cost as a bid. The contractor with the lowest bid is awarded the project. Here again, the contractor can obtain a pay increase by achieving a lower-than-targeted estimate of life cycle cost.

Much knowledge has been gained in recent years on the relationship between construction quality and construction performance. Today, the weak link in the advancement of quality assurance seems to be lack of knowledge about the costs of quality and performance. Any quality assurance effort to specify or increase the level of construction performance needs to pay proper attention to the cost elements.

Myth No. 3—With the Evolution of Specifications Come Continual Improvements in Quality

Specifications evolve as a result of two general factors:

1. Advances in engineers' knowledge of and experience with the product being specified, including the materials, processes, and equipment
2. Political, economic, and societal demands placed on the product or on those responsible for the product

The first factor leads to product quality improvements and/or to more cost effective ways to produce the product. The second factor, however, does not necessarily lead to quality improvements.

There are many examples of specifications evolving due to items that fit into the second factor. One example is the increased use of waste or recycled materials in highway construction. Waste and recycling programs may be driven more by environmental concerns than by the need for quality and performance improvements. The dwindling supply of natural resources has given little choice but to view entire pavements as potential aggregate sources that can be recycled.

The seemingly continuous downsizing of agency personnel is another example where specifications are forced to evolve with little regard for their impact on quality. Faced with personnel reductions, some agencies are attempting to "do more with less." Other agencies are delegating acceptance testing duties to the contractor in charge of construction and in effect "doing less with less." Such agencies have placed themselves in the uncomfortable posi-

Archived

tion where their role is primarily to validate the contractors' test results.

Yet another example is the steady increase of new dryer drum hot-mix asphalt plants since the 1970s, resulting in a decline in the percentage of batch plants. Dryer drum plants offer important advantages over batch plants in producing more tonnage per hour, operating more economically, and emitting fewer pollutants. However, dryer drum plants cannot supply several different mix designs in the same production run easily (that is, without multiple additional silos, which would not be feasible for portability). Although they cost more to operate, batch plants also have advantages: They have the ability to switch mix specifications—in the middle of a truck if needed—and there is more control over individual components of the hot mix, such as aggregate size and gradation control. In the 1997 *Roads & Bridges* article, "How to Choose the Right Asphalt Plant," the author writes, "A batch plant's strength lies in its ability to make salable hot mix out of almost any reasonable stockpile of aggregate."

The above examples illustrate how political, economic, and societal demands often conflict with and outweigh quality considerations. As specifications evolve partly in response to these demands, the quality being specified does not necessarily increase continuously.

Myth No. 4—Quality Assurance Specifications Provide Higher Quality Than Method Specifications

This too is not necessarily true. The truth is that quality assurance specifications have the *potential* to yield a higher quality.

Under method specifications, the contractor follows agency-prescribed methods while using agency-approved materials and equipment. The resulting construction quality is thus dependent on the methods, materials, and equipment described in the specifications. The resulting quality is the minimum quality level described in those method specifications. Under these specifications, the low-bid contractor has no incentive to use better methods or materials that will result in a higher quality than that corresponding to the specified methods and materials.

On the other hand, the contractor working under quality assurance specifications typically does have an incentive, in the form of positive/negative pay adjustment provisions, to provide as high a quality as is profitable. Thus, assuming the same minimum acceptable quality level is specified, properly developed quality assurance specifications can result in higher quality than method specifications.

The problem is that the vast majority, if not all, of comparisons of the quality produced under different types of specifications (whether they be method, quality assurance, or warranty) are made without ascertaining the quality levels being specified. Apples are not being compared to apples. It stands to reason that if the quality level specified under method specifications is greater than that specified under quality assurance specifications, the method specifications will result in a higher quality, unless the difference in specified levels is so small that the incentive effect becomes significant. For example, if an agency specifies methods under the method specification that lead to an Initial International Roughness Index (IRI) of 40, that method specification is likely to result in better smoothness (lower IRI) than a quality assurance specification designed to provide an initial IRI of 80.

The whole point of specifications is that they are supposed to tell the contractor what the agency wants. If the agency wants higher quality (within reason), it should be able to describe that desired quality level regardless of the type of specifications it chooses to employ. Certainly, the best indicator of the quality to be achieved on a project is the quality level being specified, not the type of specifications. The easiest and most straightforward way for an agency to obtain high quality construction is simply to ask for it—that is, to specify it.

Myth No. 5—Percent Within Limits (PWL) Is the Ideal Quality Measure

The PWL, or its complement the Percent Defective (PD), is currently the recommended statistical measure of specified materials and construction quality. Ninety percent within limits (that is, 10 percent defective) generally is considered an acceptable quality level. The basis for recommending PWL is that it nicely combines two important parameters, the mean and the standard deviation, into a single quality measure. For most acceptance quality characteristics, PWL provides a better measure of specified quality than the other single measures, such as the average, moving average, average absolute deviation, conformal index, and various other quality indexes.

However, PWL is far from an ideal measure. Its major shortcoming is that a given specified PWL

Archived

can describe an infinite number of populations. In the Possible Asphalt Content Populations chart, all three represented populations have 15 percent defective, yet each will result in a different pavement performance because too much asphalt content leads to bleeding and loss of skid resistance, and too little asphalt content leads to early deterioration.

This leads one to conclude that PWL does not correlate strongly with performance. Thus, the use of the PWL quality measure is problematic for highway agencies seeking to develop pay adjustment schedules that truly relate measured quality to expected performance and to the contractor's pay factor.

Agencies need to clearly specify the quality level they want. Instead of trying to specify through an ambiguous single quality measure such as PWL, agencies should consider another option—two quality measures. The typical way to describe a normal distribution population is by its mean and its standard deviation. Several agencies have used this approach successfully in developing pay adjustment schedules that relate various combinations of mean and standard deviation to contractor pay factors. FHWA's *Guide to Developing Performance-Related Specifications for PCC Pavements* (FHWA-RD-98-155) describes such an approach.

Myth No. 6—All Pay Adjustment Schedules Provide an Incentive for Quality

The Transportation Research Board's Circular Number E-C037, "Glossary of Highway Quality Assurance Terms," makes a distinction between a pay adjustment schedule and an incentive/disincentive provision. According to the glossary, an incentive/disincentive provision is "a pay adjustment schedule that functions to motivate the contractor to provide a high level of quality." The glossary further states: "A pay adjustment schedule, even one that provides for pay increases, is not necessarily an incentive/disincentive provision, as all possible pay adjustments may not be of sufficient magnitude to motivate the contractor toward high quality."

A pay adjustment schedule must be developed properly if it is intended to serve as an incentive/disincentive provision. To develop the provision for a given quality characteristic such as strength, asphalt content, or smoothness, the agency should first understand the relationship between quality and the cost to the contractor of achieving that quality. Unless the agency has a feel for how much it costs contractors to achieve higher quality strength, for example, the agency does not know whether its pay schedule for strength provides the contractor sufficient incentive to produce a higher quality strength.

What complicates the matter, however, is that most agencies develop not one but several schedules designed to function together as a pay adjustment system. These agencies typically employ various composite equations to combine the calculated pay factors for each individual quality characteristic. A composite pay factor equation often includes caps to define the minimum and/or maximum composite pay factor allowed. In some cases, the inclusion of caps makes it more profitable for a contractor to target a decreased quality level for one or more individual quality characteristics and still be assured of obtaining a high composite pay factor.

Agencies that have pay adjustment schedules should do a thorough check to determine whether they are true incentive/disincentive provisions. The University of Florida currently is developing computer software for that purpose, called Prob.O.Prof, an acronym for Probabilistic Optimization for Profit. Using the software, a State or local department of transportation (DOT) should be able to identify those pay adjustment schedules and systems that may not provide an incentive for quality. Contractors also should be able to use the software to establish optimum target values that will result in maximum profit.

Myth No. 7—Agencies Need Not Measure Materials and Construction Quality on a Warranty Project

This is totally untrue. The use of warranty specifications does not eliminate the need for agencies to measure quality during construction. In fact, during this time period when new warranty specifications are being developed and tried, the need for quality testing is of utmost importance.

Many agencies currently using warranty specifications already require some minimal testing to establish whether the contractor has achieved the specified quality levels on key characteristics, such as thickness or strength, and therefore can be relieved of the responsibility for certain corrective or remedial actions that may be necessary later. Other important reasons why agencies should measure quality on warranty projects are the following:

Archived

- *To determine whether quality is improving.* Are materials and construction quality better, worse, or the same under new warranty specifications or under the current specifications? Do warranty specifications, once the contractor has sufficient experience with them, promote continuous quality improvement?
- *To establish or validate the relationship between quality and performance.* What levels of quality need to be built into the construction to achieve various levels of product performance?
- *To obtain an estimate of how the delivered product will perform*. When can maintenance and repairs be expected? How long will the product last?
- *To identify the possible causes of poor performance.* What went wrong? What test data will the dispute resolution team need?

The introduction of warranty specifications has created a shift from agency acceptance of product quality during construction to agency acceptance of product condition at the end of the warranty period. Under warranty specifications, the agency needs to establish a strong independent quality assurance program, or, better yet, a strong independent performance assurance program. Either way, agency testing of quality during construction is something that agencies cannot afford to do without.

Myth No. 8—Buyer's and Seller's Risks Should Be Balanced

Buyer's (agency) and seller's (contractor) risks are nothing more than probabilities. Simply stated, the buyer's risk is the probability that poor-quality construction will be accepted, and the seller's risk is the probability that good-quality construction will be rejected. For the development of a construction acceptance plan, the objective is not to balance the risks themselves but to balance the multiplied product of the risks and their consequences.

Little guidance is available on the relative appropriate size of buyer's and seller's risks. The National Cooperative Highway Research Program (NCHRP) Report 17, *Development of Guidelines for Practical and Realistic Construction Specifications,* suggests the risks shown in the Buyer's and Seller's Risks table on this page. The table has served to generally define what can be considered appropriate levels of risk, but one should note:

1. The buyer's and seller's risks are not balanced (that is, not equal).
2. The balancing involves the size of the risks and their consequences. Highway agencies should be able to better pinpoint the optimum risks for specific quality characteristics and specific consequences. To do so requires an understanding of operating characteristic (OC) curves.

A simple subjective way to arrive at the "optimum" risks is for an agency and its contractors to examine together the OC curves for a given acceptance plan. If either party is not satisfied with the risks, adjustments can be made to the plan, resulting in revised OC curves. An iterative process of adjusting the plan and examining its OC curves can be followed until a satisfactory compromise has been reached.

To arrive at the optimum risks more objectively should not be too difficult. The process involves economic decision theory and, like the subjective approach, requires an understanding of OC curves (probabilities) and economics (cost of consequences). Through such an approach, an agency also can determine the optimum sample size (that is, the number of samples, n) necessary to minimize the cost of its acceptance plan. For a given acceptance plan, the larger the n, the greater the costs associated with testing; however, the larger the n, the lower the buyer's and seller's risks (that is, the lower the probability of incurring costs associated with undesirable consequences).

Summary

The field of quality assurance is full of myths. A few of the more common ones, discussed here, are all simple or absolute statements that sound good or look good at first glance. Rather than fall into the trap of believing all simple and catchy statements, the quality assurance practitioner should give such statements due consideration and thought. Once a myth is identified, a better conceptual understanding can be reached, promoting more of the out-of-the-box thinking that is necessary for quality assurance to keep progressing.

Archived

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Reprinted from *Public Roads,* May/June 2005.

Archived

What If We Changed the Way Highways Are Built?

by Charles Churilla

A visionary approach to building roads…faster, safer, and of better quality.

Archived

In 1920, rocket pioneer Robert H. Goddard outlined the possibility of rocket flight to the moon. The scientist was promptly ridiculed by no less than *The New York Times*, which erroneously stated that a rocket could not work in the vacuum of space. But when Apollo 11 landed on the lunar surface in 1969, *The New York Times* issued a belated apology to the late Professor Goddard. Today, Goddard's words on the importance of dreams are still meaningful, "It has often proved true that the dream of yesterday is the hope of today, and the reality of tomorrow."

Too often, "impossible dreams" are looked to not as inspirational motivators to achieve great things, but rather as the subject of derision as foolish fantasies. Yet, it is just such goals that move us ahead as a civilization. Without impossible dreams and their dreamers, the world would not have electric lights, automobiles, penicillin, or overnight delivery.

The highway community has its own "impossible" dreams, such as roads without traffic fatalities and without congestion caused by construction. Those dreams are matched by the public's frustration with the way highways are built and maintained. Often people ask why roads are constantly being torn up, why roads don't last longer, and why there are so many orange cones and barrels on the highways.

These concerns reflect the feelings of the Nation as a whole, as demonstrated by several national surveys undertaken by the Federal Highway Administration (FHWA) a few years ago. In *Moving Ahead: The American Public Speaks on Roadways and Transportation in Communities* (FHWA-OP-01-017), the FHWA researchers concluded, "Improvements in traffic flow, pavement conditions, and work zones may result in the greatest rise in traveler satisfaction. Work zones are especially critical [because] travelers view road repairs as a major reason for traffic delays."

The State of the Existing System

The transportation community has designed and built highways in this country virtually the same way for 70 years or more. Unfortunately, this approach is no longer keeping pace with the growing demand. Statistics reveal the dilemma:

- According to a Texas Transportation Institute (TTI) study of the Nation's 75 largest urban areas, the average annual delay has climbed from 16 hours per person in 1982 to 62 hours in 2000. TTI estimates the cost of congestion at $78 billion in 2001.
- Approximately 15,000 highway fatalities result annually from crashes in which substandard roadway conditions, obsolete designs, or roadside hazards are a factor.
- The average age of the 257,600-kilometer (160,000-mile) National Highway System (NHS) exceeds 35 years, well beyond the original pavement design life.
- More than 17,710 kilometers (11,000 miles) of NHS pavements are currently in poor condition.
- Nearly 24,000 of the interstate bridges currently are classified as "deficient."

Clearly, something has to be done because highways are, after all, the backbone of the Nation's transportation system. Nearly all products and services travel over highways, and U.S. citizens depend upon highways to commute to work and for personal trips. But just like a favorite restaurant that now has a 1-hour wait for a table, highways are suffering under their success. The only way out is to find a better way.

Here is a potentially impossible dream: What if engineers were able to build highways that are safer,

smoother, quieter, and overall have better quality—in days, not months or years—and have them last 50 years? A tall order? In reality, this dream is no more impossible than Goddard's. A significant number of proven technologies and practices currently exist to achieve safer highways, reduce congestion due to construction, accelerate highway construction, and provide longer-lasting highways. However, a great deal of this innovation and advanced technology is practiced on special projects or has not risen to the level of common practice.

The rate of adoption of new technologies and practices creeps along at a snail's pace. As FHWA Deputy Administrator J. Richard Capka put it, "What is needed is to bring about a leap, instead of creep, in their use." Without dramatic changes in how the transportation community promotes, delivers, and deploys innovations and technologies, the realization of better ways of building highways would take decades.

Can It Be Done?

Innovative technologies and practices employed to speed construction and improve safety and quality already exist and are being used today. Commonly cited as examples of rapid repairs are the replacement of the collapsed I-40 bridge over the Arkansas River in Oklahoma; the reconstruction of the I-65 bridge in Birmingham, AL, after a fire; and the repair of roads and replacement of the freeways and bridges in California following the Loma Prieta earthquake. The impact of these projects mandated that virtually all project-related functions happened simultaneously rather than sequentially and at a greatly accelerated pace. But although such projects might be thought of as excellent examples of how to get projects rebuilt quickly and safely, in actual fact they were simply unique exceptions to how business is typically done. Because they were emergencies, they required immediate action with an associated need for extraordinary staffing and funding.

But what if the transportation community took the best practices and lessons learned on these emergency projects and applied the principles to *everyday* projects that are developed and delivered by highway agencies and the construction industry across the Nation, every day, as part of routine business? Such projects currently are being built throughout the country—so many, in fact, that a separate article, "The Future Is Now," in this issue of *Public Roads* describes them. These exemplary projects were delivered quickly with improved safety and reduced construction congestion, and they should last longer. In some cases the initial cost of construction is lower.

If agencies wanted to change how highways are built and delivered, what would it take to bring about rapid change? Guiding principles for consideration in planning a new way of building and delivering highway projects might include:

- Do the "never been done"—by breaking out of one's comfort zone and changing attitudes from "I can't and won't" to "I can and will."
- Involve stakeholders—from the transportation community and highway users—in the development and conduct of the program.
- Utilize proven successes—technologies, materials, processes, and practices—in the financing, design, construction, and operation of highways.
- Be bold and audacious—break the mold to "leap and not creep." Implementing proven technologies and innovations will result in significant benefits by producing safer highways, reducing construction congestion, and building longer-lasting highways.
- Keep the focus—on the motorists and highway users.
- Improve safety—not only during the construction phase, but also to provide a safer highway after the orange barrels are gone.
- Reduce congestion due to construction—by accelerating the onsite phases of construction process and employing the best technologies and practices in the management of work zone traffic. Note that accelerating construction does not always translate to more people, more equipment, or more overtime. Sometimes it simply means planning the project more carefully and doing more advance work, so that the project can be completed more quickly once the road closure is in place.
- Extend road life significantly—by increasing design life, using innovative materials, and practicing preservation.
- Improve highway quality—to levels that represent the best of what the transportation community produces.

Archived

Changing the Focus

One approach to bringing about such a paradigm shift is to change the focus. Rather than telling builders and suppliers how to build a project, they should be given a description of what the end product must "look like," in terms of performance standards. The standards should be based on the needs of motorists, such as pavement smoothness levels, safety criteria, and the like. Then, working together, the transportation agency, the contractors, and the suppliers can devise innovative ways of getting the job done.

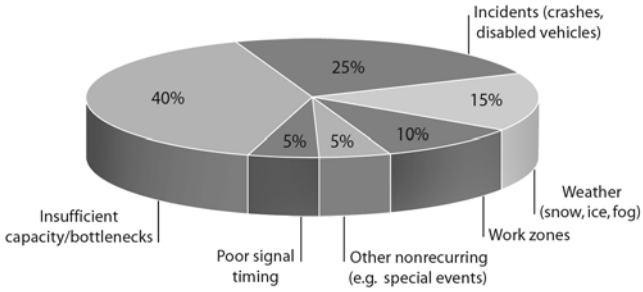
An example is Colorado's Mitchell Gulch Bridge, replaced in 2002. The Colorado Department of Transportation (DOT) had envisioned a traditional box culvert design for the new bridge, which would have required 2 to 3 months of detours and delays on the road. Through the use of precast structural units, extensive planning, and other "value engineering" concepts, the bridge was replaced within 48 hours, over a single weekend. As this project showed, performance standards foster innovation and adoption of best technologies and practices. To be effective, the standards should represent the best of what the highway community has and is able to produce.

With user-focused performance standards in hand, the DOTs, the contractors, and suppliers can work together to develop solutions that show the driving public what is possible. And as more and more projects are built using performance standards and the tools and technologies they foster, perceptions will change about how impossible the dream really is. How many projects? Enough to span a wide range of project sizes, types, and locations. Enough to counter the reaction, "It won't work in my State or under these conditions."

To persuade these organizations to start building highways and bridges with such an approach, however, will require incentives and assistance to encourage and promote innovation. Another key ingredient would be to find ways to make it easier for agencies to undertake projects that would show the highway community, the public, and the media how such projects that meet user-focused performance standards are built. By using innovations and technologies, State and local DOTs will present their customers with a clear picture of their capabilities, and at the same time they will be meeting the expectations and needs of these customers.

Causes of Highway Congestion

How is the congestion pie sliced?



Total delay: about 4 billion hours per year.

Source: FHWA

But building a few projects will not be enough to bring about the newer way of building and delivering highways. Even if a percentage of the projects were paid for in order to motivate agencies to build them under the new approach, once the money was spent, there would not be a change in culture. Agencies would go right back to building roads the traditional way.

To move the entire highway community into this new performance standard-driven approach, leaders from various areas of the transportation community will have to step forward. These stakeholders will have to participate in developing a program and in delivering the innovations.

If the goal is to be successful in promoting change in the way the industry thinks about and manages projects, Federal, State, and local transportation agencies will need to develop, equip, and train a workforce to embrace these new innovations and technologies. Transferring technology to users in the field should include training for personnel in the public and private sectors; education at the technical, associate, undergraduate, and graduate levels; Web-based information systems that include all the innovative tools and techniques; a lead State (in business, this would be the "early adopter" phase of a product/project life cycle) program similar to the Strategic Highway Research Program implementation effort; and workshop and showcase events.

In the final analysis, clear evidence is essential that the cultural change in how projects are built is worth the energy and investment, as is evaluation of

Archived

results and clear documentation of the benefits. Widespread demonstration of successes would, in turn, provide the impetus for more extensive application of the innovative methods and technologies in the future. Documentation would involve collecting facts and figures on construction conditions, costs, results, outcomes, and benefits prior to construction, during the work, and after completion of the project. One use for the documentation would be to employ it for teaching the concepts and applications to others in the transportation community.

If a new method of building and delivering highways is to become standard practice, communicating the information, new practices, and new innovations is critical. Without a high level of communication, innovative approaches would remain with those who initially developed or employed them. In addition, recounting the successes and lessons learned by other agencies tends to instill a higher level of understanding and appreciation of the challenges as well as the benefits. There is also a bit of "keeping up with the Joneses" involved, where learning of the successes of one's neighbors can build a friendly spirit of competition and a desire to keep up with the rest of the transportation community. Telling the public about the highway community's push for better roads builds goodwill and shows an appropriate level of response to motorists' needs. Finally, communication has the potential of demonstrating to the local highway builders the benefits of using innovative tools and technologies on more of their projects.

Innovations on the Fast Track

Fostering innovations would facilitate the implementation of innovative technologies that would enhance the safety and speed of highway construction and the safety characteristics, quality, and durability of pavements and bridges.

The purpose of fostering innovations is to:

- Stimulate investment in innovation and accelerate deployment
- Provide improved tools to facilitate achievement of performance standards
- Provide broad access to the innovations that goes well beyond those involved in constructing a few projects
- Provide an improved technology infrastructure to support highway safety, construction, and quality

To foster innovations, it would be necessary to provide the financial impetus to move proven but underutilized market-ready technologies and methods into practice. Although research and development are important, the emphasis of an effort to foster innovation should not be on research, but rather on innovations, technologies, practices, or procedures that have been used successfully in some venue or have demonstrated a clear potential for successful use in the U.S. highway industry, in associated or similar fields, or internationally.

What Would Success Look Like?

So what would be accomplished as a result of such an effort to bring about changes in building highways and roads? The transportation community might anticipate four major results: First, by building a sizable number of projects throughout the country using new methods, a broad and dramatic improvement in the American driving experience could be demonstrated. Second, a new culture of meeting the needs of the customers could be created. Third, an impetus to build on success would be produced, so that the new approach sticks long after the initial push for change has passed. And finally, an atmosphere that can accommodate and sustain rapid change and adoption of new innovations might be created.

Landing a man on the moon within 10 years seemed a big stretch in May 1961 when President John F. Kennedy issued his challenge to do exactly that. It was even more of a dream back in 1920. Yet space flight and even the concept of lunar exploration have become part of today's reality. Goddard's statement that the dreams of yesterday can become

Archived

Can You *Really* Cut Construction Time Without Paying More?

Some observers have expressed concern about the feasibility of building highways faster, cheaper, and with better quality without having to sacrifice any of those objectives. Years ago, someone came up with a chart that listed cost, time, and quality as three points of a triangle. And the idea was that you could get a high level of achievement on any two, but the third would have to be sacrificed. If, for example, you wanted to do a high-quality job, and you didn't want to give up any time, you'd have to pay more for it. That approach assumes, however, that highways would continue to be built employing the same methods that have been used in the past. Using traditional methods may mean working nights or weekends to cut construction time, which requires overtime and thus an increase in costs. But, instead, what often happens is that a contractor may find innovative ways of building the project —outside the box—given the right incentive.

A 1999 project in Kansas, described by Martin Miller of the Kansas Department of Transportation (KDOT), did just that on a 12-kilometer (7.5-mile) section of Interstate 135 (I–135) south of Newton. The project, which won a National Award for Excellence from the American Concrete Pavement Association, was ranked "excellent" for innovations related to construction schedule, public involvement, and overall quality of construction.

The first innovation, an accelerated construction schedule, was suggested by the engineering staff at KDOT District Five after an office review of the construction plans. The project originally was slated to be completed in two construction seasons, but from experience with similar projects, District Five engineers felt confident that contractors working in Kansas could construct it in one season. So contractors were given the option of providing two bids, one for completing the work in 2 years and one for a 1-year completion.

When the project was opened for bids, the winning company submitted the lowest overall bid for the 2-year option ($18.5 million) and also submitted a bid for the 1-year option at $1 in additional cost. KDOT selected the 1-year schedule to reduce disruption to the traveling public.

In addition, KDOT added financial incentives to the contract to speed reconstruction of the interstate ramps at Exit 28 (SE 36th Street). Of the three sets of ramps on this section of I–135, Exit 28 was the most heavily traveled, serving an outlet shopping mall and the surrounding business community. The contract included a 40-day maximum closure for each ramp, a $2,000 per day disincentive for each day over that period. To alleviate local concerns over the impact of an extended closure period, KDOT added a $2,000 per day incentive to the contract for early completion of the ramps. Because of the incentive, the ramps were rebuilt in 23 days, reducing the closure period and resulting traffic disruption by 17 days.

Efforts to involve the public began prior to construction. Monthly public meetings were held at a food court in the outlet mall, near the high-profile interstate interchange. The construction work was one item on the agenda of the monthly meetings already scheduled for outlet store tenants and surrounding businesses.

Two main concerns surfaced during the public meetings. The first was that local businesses did not want the Exit 28 ramps closed during holidays. The contractor adjusted the original ramp construction schedule accordingly. The second concern was, "How will our customers find us during this ramp closure period?" In response, the management of the mall posted signs directing customers from the nearest open I–135 interchange, using local roads. To reduce driver confusion and possible crashes, KDOT put up a variable message board in the work zone giving travelers information on the open ramp. This cooperative signage effort was supported by the county and the city's chamber of commerce.

KDOT also offered incentives related to the quality of construction. A $93,000 smoothness incentive was paid as a result of the pavement profile on the project. A $302,000 quality incentive was paid as well. Due to the cooperative efforts of KDOT and the contractor, and the company's proficiency, the project was completed far ahead of the accelerated schedule and has proven to be a high-quality highway improvement.

When agencies talk about incentives in highway construction, it sometimes appears as though contractors are receiving a lot of extra money when they meet the criteria for the incentives. One thing to keep in mind, however, is that most of these projects still are contracted using a "low-bid" process. Contractors who know how to do the job well will factor the incentives they expect to earn into their bid price, thereby reducing the bid price by the anticipated incentive amount.

Archived

the reality of tomorrow might give the transportation community hope that with leadership, vision, a plan, and the support of a wide array of groups and individuals, a better way of building highways can truly be tomorrow's reality.

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Reprinted from *Public Roads,* May/June 2004.

Toolbox of Knowledge

Conceptually, a toolbox would provide a central repository of information that transportation agencies and the highway construction industry can use to identify best practices and innovative technological, contracting, and financial tools that may be useful to a particular project, as well as resources for additional information and guidance on the application of those tools. In reality, the toolbox would likely take the form of a Web-based reference tool, which would contain additional resources that agency and highway industry personnel can access for help in identifying technological, contracting, and financing tools and methods that may be applicable to their particular projects.

Archived

The Future Is Now

by Kathleen Bergeron

These snapshots of successful projects from around the country show that the stage is set for a new approach to highway design, construction, and maintenance.

In this issue, several articles pose a "what if" question about a new vision for highway development. The approach envisions the construction of long-lasting roads using innovative technologies and practices to accomplish fast delivery of efficient and safe pavements and bridges. But is this approach easier said than done? Are there examples out there now, demonstrating what is possible?

State departments of transportation (DOTs) and their partners already are implementing many projects employing one or more innovative approaches or technologies. And these examples are not all mega-budget projects; several cost only a few hundred thousand dollars to complete. Nor are they all emergency projects executed in response to crisis situations. Clearly, emergencies represent unique situations where highway officials set aside the need to hold lengthy public hearings and develop numerous design options because of the necessity of getting a facility back into service quickly.

The following examples demonstrate the diversity of ongoing projects. And they are not limited to one or two States but are scattered throughout the country.

Alabama Employs Incentives to Replace Bridge

On January 5, 2002, a loaded gasoline tanker traveling north on Interstate 65 (I–65) within the I–20/I–59/I–65 interchange in Birmingham, AL, crashed and burned under the I–65 southbound bridge. The fire caused the steel girders of the main span over southbound I–65 to sag about 3 meters (10 feet), which required closing both northbound and southbound I–65. Removal of the damaged bridge began as soon as the wreck was cleared, and northbound traffic was restored on January 6. The road user cost resulting from closure of the southbound bridge was estimated at $90,000 per day.

The department designed a new concrete girder bridge and awarded the contract on January 16; construction started on January 21. The contract allowed 90 days for completion of the new bridge with an incentive/disincentive provision of $25,000 per day. The successful bidder completed the new bridge in 37 days, earning a $1,225,000 incentive. The contract cost, including the incentive payment, was still less than the cost proposed by the second bidder.

"Within 53 days, the damaged bridge was removed, the design completed, and a new bridge built, demonstrating intense commitment and cooperation among all parties involved—especially State engineers, the concrete fabricator, and the contractor that built the new bridge," says Division Administrator Joe D. Wilkerson with the FHWA Alabama Division.

Alaska Upgrades 18 Bridges With Precast Concrete

Deadhorse, AK, is located on Prudhoe Bay, where the Alaska oil pipeline originates in the North Slope oil fields. Although the 668-kilometer (415-mile) Dalton Highway has an average daily traffic count of only 250 vehicles, the highway is critical to Deadhorse because it is the only road connecting the community to the outside world and carries all supplies for the oil field. In 1992, the Alaska Department of Transportation & Public Facilities began replacing the timber decks with precast concrete slabs on 18 bridges on the Dalton Highway between Fairbanks and Deadhorse. Instead of continually replacing the timber decks every 8 years, the agency decided to use precast concrete panels that would last for approximately 50 years, resulting in savings in the cost of replacing the timber decks and in recurring impacts on the traveling public.

Archived

During reconstruction, the timber decks were replaced with full-width precast concrete slab units. Through negotiations with the trucking and tour bus companies, the department agreed that the road could be closed completely to traffic for 12 hours each day. During this period, the contractor removed sections of the old timber deck, welded new shear studs to the top flange of the steel girders, placed the precast slab units (which had block-outs to accommodate the new shear studs), placed quick-setting mortar in the block-outs, and then reopened the road to traffic. This process continued until each bridge was completed. The construction technique enabled the department to redeck the bridges in approximately 7 months, with minimal impact on truck traffic.

Arizona Uses Innovative Bidding for HOV Project

The Arizona DOT is widening SR–51 (Piestewa Freeway) between I–10 and Shea Boulevard in Phoenix, AZ. Adding high-occupancy vehicle (HOV) lanes in each direction will make a direct connection to the existing HOV lanes on I–10 at the south end of the project, representing a substantial extension of the HOV concept in the Phoenix metropolitan area. The connection to I–10 provides a smooth and efficient link between HOV lanes on the intersecting freeways.

"Such linkages have been a major challenge for highway engineers across the country," says Ken Davis, a senior engineering manager with the FHWA Arizona Division. "With the additions of this project, drivers will have no need for extensive lane changing to transition from HOV lanes on one freeway to HOV lanes on another freeway."

The project employs a design-build contract and includes the A+B bidding (cost plus time) concept as well. Together, these two contracting methods have fostered considerable innovation and creativity in tackling this major freeway expansion in a confined corridor, while substantially reducing the length of construction (only 330 days instead of the 480 days originally anticipated) and the extent of traffic disruption. Full-weekend closures are enabling the contractor to make maximum progress during periods of lower freeway usage. In addition, the project incorporates substantial intelligent transportation systems (ITS) features and enhances the Freeway Management System in the Phoenix metro area.

The project also provides an asphalt-rubber friction course surface (quiet pavement) throughout—in part to hide existing pavement joints and facilitate relocating lane markings, but also to provide an additional measure of noise mitigation. "This is a very significant feature—the adjacent neighborhoods have complained for years about this freeway's high noise levels," Davis says.

California Repaves a Major Freeway

Interstate 710 is 46 years old and heavily traveled, averaging 157,000 vehicles per day, with one of the highest concentrations of deteriorated pavements in California. Trucks carrying cargo from the ports of Long Beach and Los Angeles account for 13 percent of the freeway's total traffic, but the original design a half century ago assumed that only 5 percent of the traffic would be trucks. Although the California Department of Transportation (Caltrans) patched the road at various locations during its lifetime, the agency never had implemented a rehabilitation project by separate contract.

A recent Caltrans rehabilitation project on I–710 between State Route 1 and I–405, just north of Long Beach Harbor, CA, involved applying long-life asphalt pavement with a life expectancy of 30 to 35 years. A task force on long-life pavements at Caltrans has been working since 1998 on this showcase project, which breaks tradition with how the department usually constructs freeway paving projects. The task force includes members from the asphalt concrete industry and the University of California at Berkeley's Pavement Research Center. "We're enthusiastic about this pilot project testing new, longer-lasting asphalt paving methods," says Doug Failing, director of Caltrans District 7. "This is the first time these creative asphalt paving methods have been used on a California freeway."

The project employed an innovative traffic management plan that consisted in part of using a traffic staging plan involving freeway crossovers. During this critical stage, Caltrans employed eight 55-hour weekend closures that enabled the department to shut down one direction of the freeway for construction while traffic was detoured to the other side using movable barriers. This made it possible to provide two open lanes of traffic in each direction throughout the extended weekends. The project also provided motorist information strategies such as an incident management program, an elaborate

Archived

public awareness campaign, and the use of more than 40 permanent and portable changeable message signs.

In 2003, the project won a Roadway Work Zone Safety Awareness Award in the category of Innovative Technologies (Methodology–Large Project) from the American Road & Transportation Builders Association (ARTBA).

Colorado Constructs Major Multimodal Project

The Colorado DOT used a design-build contract for the $1.2 billion Transportation Expansion Project (T-REX), a transit and highway project in the Denver metropolitan area, leading to significant savings in time and cost. By combining light rail, highway, bike, pedestrian, and other transit options, T-REX represents a multimodal approach to addressing traffic problems. Packaging the project into a single design-build contract creates economies of scale and significant cost savings because construction can begin before the final design is complete. The combined packaging also allows for more innovations in design and construction techniques, creating further cost savings.

Innovations in construction resulted from the latitude afforded the contractor. Retaining walls, for example, were constructed at the right-of-way using drilled caissons, which later were exposed on the roadway side and covered with fascia panels—precast concrete panels that give the appearance of a concrete wall when the actual retaining wall is formed by shoulder-to-shoulder caissons. This technique enabled the contractor to construct the wall before excavation was complete. Normally, to widen the highway in a section where the roadway is below the surrounding ground, the excess material would be removed and a retaining wall would need to be constructed. Under the design-build contract, construction of the wall commenced immediately with the drilling and placement of caissons, and excess material was removed when access became more favorable. The use of caissons, instead of a retaining wall and footing, also allowed for a smaller wall construction area.

Connecticut Installs Bridge Overnight

To minimize disruption to train service and eliminate the difficulty of building a bridge over active rail lines, the Connecticut DOT specified that a portion of the Church Street Bridge in New Haven, CT, be completed in a single night operation over a weekend. After months of building the structure alongside the active lines of the New Haven Interlocking and Rail Yard, the contractor lifted and set the bridge into place at 2:30 a.m. on Sunday, May 4, 2003.

The bridge span, a 97.5-meter (320-foot) truss weighing more than 771 metric tons (850 tons), is the main segment of the 390-meter (1,280-foot) bridge. The new bridge and roadway extension will connect New Haven's Union Avenue with Sargent Drive and provide an alternate route for traffic heading to the downtown, Sargent Drive, and Long Wharf areas of the city.

This was the first time that the Connecticut DOT built a structure offsite and lifted it into place using the largest mobile, land-based, and high-capacity crane in existence. The crane was delivered in more than 200 tractor-trailer loads of parts and required more than 4 weeks to assemble. The crane lifted the entire truss span more than 20 meters (65 feet) into the air and carried it more than 30 meters (100 feet) toward the tracks, where the span was set in its final position. The Connecticut DOT estimates that this accelerated construction method saved approximately 1 year on its overall contract time.

Florida Uses Design-Build Process and Unique Work Zone

After a series of crashes involving fatalities in the spring of 1999, the Florida DOT (FDOT) funded a project to widen the Panasoffkee Creek Bridge, carrying I–75 through Sumter County. The existing structure featured two lanes in each direction with 0.9-meter (3-foot)-wide inside and outside shoulders.

The project involved widening the existing bridge to accommodate a six-lane facility, with standard shoulders and bridge railings. The project also included upgrading the acceleration lane for the interchange at County Road 470, which required widening the approach to the northbound I–75 bridge by 244 meters (800 feet) to improve the safety of the merge area. The challenge was to widen the existing bridge by closing the 16.5-meter (54-foot)-wide median without interfering with the high volume of traffic on I–75.

"Major goals for the project were to provide a safe work zone for the employees and public, and to build the project quickly," says Michael McCammon, an operations engineer with FDOT. "The theme 'get

Archived

in, get out, stay out' is common in transportation projects in Florida, and the Panasoffkee Creek Bridge project in particular embodied this ideal."

Using the design-build process, FDOT minimized lane closures, adhered to an aggressive schedule, and brought the project from concept to completion in approximately 3 years (instead of the traditional 7) at a cost 42 percent less than estimated for traditional design and construction approaches. In addition, the project marked the first time that Florida used a travel lift crane to construct a bridge. The crane used rails, supported on the median edges of the two existing bridges, and ran the entire 1,367 meters (4,484 feet) of the structures, facilitating safer delivery of materials and equipment without lane closures.

The construction contractor also devised an innovative method to access the work zone in the median. By purchasing the property adjacent to the interstate, the company enabled workers to park nearby and access the median by walking on the existing embankment under the northbound bridge, and then using a temporary aluminum bridge to access the median at the end bent. "This innovation," says McCammon, "contributed to the project's outstanding safety record."

Georgia Turns to Full Road Closures to Reconstruct I–285 Segment

Reconstruction of I–285 between I–675 and I–20 in Atlanta required a 25.4-centimeter (10-inch) mill and inlay, all the way to the old PCC pavement. The unusually deep mill was prompted by a stripped layer of asphalt that had been placed over the old PCC pavement in the late 1970s. The inlay consisted of approximately 17.8 centimeters (7 inches) of Superpave,™ 3.8 centimeters (1.5 inches) of stone matrix asphalt, and 3.2 centimeters (1.25 inches) of coarse, open-graded friction course.

Despite traffic volumes of 120,000 vehicles per day, GDOT and FHWA determined that the most effective way to complete the job would be to shut down I–285, one direction at a time, on weekends only. GDOT estimated that reconstructing the 103 kilometers (64 lane miles) of pavement would take 11 weekends in each direction. The project would have taken more than 2 years using conventional nighttime construction methods. "By closing I–285 in the direction of the work and detouring traffic," says James McGee, a Georgia DOT construction engineer, "we were able to accomplish the work in a much shorter amount of time, which caused less overall impact on the traveling public."

The project involved massive preparations, including media campaigns, mass mailings, community meetings, and dynamic signing to get the word out to the public. GDOT orchestrated detours onto I–75 and I–20 to bypass I–285. During reconstruction, GDOT added to the project scope by reconstructing shoulders, upgrading guardrails, and installing a conduit for an advanced transportation management system. Using four pavers and eight milling machines, contractors paved an average of 12.9 kilometers (8 lane miles) of the deep mill and inlay each weekend. The entire project, including paving and roadside work, was completed in only 12 weekends—6 for each direction.

With the road closed to the public, trucks delivering construction materials to the site did not have to wait in traffic, which ensured a constant supply of fresh material. "As a result," says Walter Boyd, a transportation engineer with FHWA's Georgia Division, "pavement smoothness and quality were excellent because the paving machines ran for hours at a time without stopping."

Hawaii Widens H–1 Through Honolulu

In Honolulu, the Hawaii DOT is adding one lane to H–1 in the westbound direction to alleviate a significant traffic bottleneck during the afternoon rush hour. Known locally as the Waimalu Widening Project, the work will involve adding a long viaduct structure—essentially an elevated overpass—that will cross over several streets and connect the community of Waimalu to other communities in the area.

The need to minimize traffic disruption is a major concern, so the new lane will be constructed under normal traffic conditions. To complete road and bridge construction quickly and efficiently, the project incorporates A+B bidding, quick-change movable barriers, and traffic monitoring and control using ITS technologies. The department expects the project to begin in the spring of 2004 and reach completion in the fall of 2005.

Indiana Hyperfix Project Fixes City Streets to Facilitate Full Interstate Closure

To rehabilitate I–70 and I–65 in downtown Indianapolis in the shortest time possible, the Indiana DOT used incentives and complete closures to traf-

Archived

fic, thereby enabling the contractor to work full time at the site.

"Full road closure facilitated completing the project in a much shorter time frame—3 months versus 2 years," says INDOT Commissioner J. Bryan Nicol. "It also resulted in better quality control, a superior product, and a higher degree of safety for the public and project staff."

A significant issue for the Hyperfix project was the potential impact on the public in terms of congestion. Closing an interstate facility for 3 months could cause significant disruptions if not planned and coordinated well. The city of Indianapolis and INDOT managed the closure from the perspective of the metropolitan region, coordinating other projects and restricting construction on I–465, the major detour route. In addition, the city completed strategic improvements to its local street system to prepare for increased traffic on alternative routes. Dubbed "Cityfix," the program resulted in $2 million in intersection and street improvements, including turn and parking restrictions, a moratorium on street cuts by utilities, improved intersections, and added travel lanes at strategic locations.

Another important strategy to reduce the impact of congestion and respond to public concerns was the establishment of a park-and ride program in the northeastern portion of the metropolitan area, the section anticipated to be affected the most. FHWA provided $1 million in funds from the Congestion Mitigation and Air Quality (CMAQ) Improvement Program to provide express coach service at three locations.

"Work zones are a dangerous environment for both workers and motorists," says Dan Rogers, an INDOT construction engineer. "The mainline closure of I–65 and I–70 not only allowed for higher quality and accelerated construction, but also it created a much safer environment for the project crew and the motoring public."

The $25 million Hyperfix project was completed on July 20, 2003, in 55 days, "exceeding everyone's expectations," according to Commissioner Nicol. "This was a significant accomplishment, 30 days under the schedule, and with the contractor reaping the maximum number of incentives."

Iowa Employs Innovative Sawing in PCC Project

While completing a widening and resurfacing project on Iowa 13 between Manchester and Iowa 3, the Iowa DOT applied a thin PCC overlay to the existing pavement and used a full-depth PCC pavement monolithic widening unit on each side as part of its strategy to ensure a long-life overlay. Innovative aspects of the project included using a longitudinal joint-forming knife, or "bobsled," rather than conventional sawing to initiate the multiple joints in the pavement. Attached directly to the paver, the bobsled creates a weakened plane by moving coarse aggregate out of the path. The result is a barely visible crack that requires no sawing or sealing.

Workers placed 1.6 kilometers (1 mile) of pavement per day, and each segment reached opening strength by the following day. Employing the proper mix-design and maturity methods, Iowa DOT could open the new pavement to automobiles 18 hours after placement and to trucks after 30 hours. The department enhanced safety and capacity by providing a wider road with paved shoulders, while minimizing inconvenience to the public during construction.

"The bobsled has the potential to not only reduce the environmental concerns associated with concrete pavement sawing, but it also may produce a better product at a lower cost," says Division Administrator Phil Barnes with the FHWA Iowa Division.

"This approach to rehabilitation, using the remains of the previous investment to the benefit of the new investment, offers significant promise to local and State officials," adds Gordon L. Smith, P.E., president of the Iowa Concrete Paving Association.

Louisiana Opens Center To Manage Traffic and Emergencies

Dedicated in January 2002, the Advanced Traffic Management/Emergency Operations Center (ATM/EOC) in Baton Rouge is a state-of-the-art facility that integrates traffic surveillance, incident detection, traffic control, motorist information, and emergency response into one management center. New ITS functions recently implemented at the center include advanced traffic signal systems, fiber-optic communications systems, and cameras and other automated equipment to monitor and count traffic, detect speed, and classify lanes. A new project on reduced visibility also is underway, involving variable message signs (VMS), variable speed signs, weather stations, and fog detectors.

The center houses the Baton Rouge emergency medical services, 911 call center, fire and police dispatch, regional traffic engineering, and the offices of

Archived

homeland security and emergency preparedness. "What makes the ATM/EOC truly unique and important to transportation is the existing and planned integration of traffic, 911 dispatch, and incident management systems," says Division Administrator Tony Sussmann with the FHWA Louisiana Division. "The different government agencies are not just sharing the same control room, they're sharing information."

Maine Upgrades Bridge Over Penobscot River

The Maine DOT is building a new cable-stayed bridge spanning the Penobscot River between Waldo and Hancock counties. In July 2003, the department discovered that deterioration of the existing main suspension cables had reduced the structural integrity of the bridge. A series of measures were implemented as short-term fixes until a replacement bridge is open to traffic.

The Waldo-Hancock Bridge, also known as the Penobscot River Crossing, will be a 646-meter (2,120-foot) single-plane, cable-stayed bridge with a segmental concrete trapezoidal box superstructure and a mainspan of 354 meters (1,161 feet). During planning, the Maine DOT considered how the towers might be used to enhance the bridge. As a result, the latest design proposal includes an elevator leading to an observatory atop one of the bridge's pylons. Windows facing all directions would provide views from 122 meters (400 feet) above the ground. The estimated cost of the project is about $70 million, and the projected opening date is June 30, 2005.

The project uses innovative contracting procedures for design and construction, and a streamlined environmental review process brought the project to construction 6 months after the decision was made to pursue a new river crossing. "It is our hope that this bridge will serve to boost the region's economy by becoming an attraction in and of itself," says Maine DOT Commissioner David Cole.

Minnesota Reconstructs Freeway Using Innovations

The primary innovation that the Minnesota DOT (Mn/DOT) is using for a project to reconstruct the four-lane Highway 52 (ROC 52) in Rochester, MN, is the design-build method of contracting.

The purpose of the project is to replace deficient pavement and bridges, thereby improving safety and the level of service. The project involves completely reconstructing and widening 17.7 kilometers (11 miles) of highway to three lanes in each direction though the western portion of Rochester, MN. The reconstruction includes 7 interchanges, 24 bridges, and installation of ITS technologies.

In addition to using the best-value method to select a contractor, the State employed a number of other innovative practices, including an integrated project management team, a comprehensive quality control/quality assurance (QC/QA) program with substantial incentives for quality performance, a built-in dispute resolution process, and concurrent design and right-of-way acquisition.

Mn/DOT expects schedule and cost benefits to include a shortened construction time (from 11 years down to 4) and at least $30 million savings in inflationary costs alone. Substantial benefits also will be realized from reduced out-of-pocket user costs, less user inconvenience (delay), and substantially lower human and monetary costs associated with crashes. Mn/DOT expects the mainline and crossroad construction on ROC 52 to be finished by the end of 2005.

Mississippi Uses Pavement Warranty on I–55

On I–55 in Carroll County, the Mississippi DOT milled an 11.4-kilometer (7.1-mile) section of hot-mix asphalt pavement and placed a concrete overlay on the four-lane divided facility. The I–55 project relied on A+B bidding to speed up construction time and was completed in 503 days, saving approximately 1 year of construction time compared to the conventional bidding process.

The project also represents the first use of a concrete pavement warranty in Mississippi. The 10-year maintenance warranty required the contractor to provide the PCC mix design, selection of materials, and construction methods.

"In the end," says Roger McWilliams, transportation engineer with the FHWA Mississippi Division, "the contractor successfully completed a project of high construction quality with an excellent ride, while saving approximately 1 year of construction time."

The American Concrete Pavement Association selected the project as a finalist in the 2003 Excellence in Concrete Pavement Awards.

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Missouri Replaces Bridge on I–70

The voided slab bridge over I–70 between Lake St. Louis Boulevard and Route 40/61 in St. Charles County, MO, was more than 40 years old, and traffic studies indicated the need for additional lanes to accommodate increased traffic. Through a value-engineering proposal, Missouri DOT's contractor suggested building a new, wider structure rather than widening the existing Lake St. Louis Bridge.

The contractor estimated that a new bridge could be built rapidly using precast deck beam sections and mechanically stabilized earth wall abutments, which would provide a two-span bridge instead of the existing four-span. Lane capacity would increase from two to six lanes, providing two through lanes and one turning lane in each direction. The cost would be an additional $500,000, but the new bridge would offer a safer clearance of 5 meters (16.5 feet) for interstate traffic, in lieu of the 4.9-meter (16-foot) clearance originally designed. In addition, the new deck beam structure would not restrict overheight loads. Finally, building the new bridge reduced the actual construction time and impact on motorists by several months.

The bridge closed on August 3, 2003, and reopened by November 24. The combination of the type of bridge (prestressed box beam) and closing the overpass during construction enabled the contractor to demolish the old bridge and erect the new one in less than 4 months. "To decrease the construction time, local officials agreed to allow the department to close the old bridge, demolish it, and build the new one," says Barry Bergman, project manager with the Missouri DOT.

By reducing the number of spans, the department improved the overall geometrics and increased the efficiency and safety of the interchange. The two-span bridge also allows for widening Interstate 70 to address capacity needs in the future. Maintenance costs decreased as well, since the new bridge was approximately 30.5 meters (100 feet) less than the original facility. An additional benefit of the new structure is that the bridge provides simple architectural enhancement opportunities (such as texturing and staining) for the city of Lake St. Louis.

Montana Issues Bonds to Upgrade U.S. 93

The segment of U.S. 93 between Evaro and Polson, MT, currently is a 90-kilometer (56-mile), two-lane rural highway that is heavily congested and exceeds the statewide average for crash rates. The Montana DOT is developing a series of projects to reconstruct this segment to address operational and safety deficiencies, at an estimated cost of $120 million. The conventional funding scenario would complete the project over a period of 15 to 20 years. The department, however, is proposing to issue bonds so that the work can begin sooner, thus accelerating completion to within 7 years.

"This funding mechanism will enable the traveling public to realize the operational and safety benefits as expeditiously as possible," says FHWA Montana Division Administrator Janice Brown.

New Hampshire to Replace Bridge Quickly

Working with the University of New Hampshire, the New Hampshire DOT plans to replace two existing bridge spans over the Lamprey River on Mill Street in Epping, NH, with a single, butted box beam superstructure supported on rapid-installation, precast structural elements. The existing bridges are deteriorated severely and are on the State's list of bridges and municipal structures that are deemed in the worst condition.

Using precast, high-performance elements and innovative contracting techniques, the department expects the new bridge will be constructed and open to traffic in just 2 weeks. With additional roadway work, the entire project should be completed in 3 to 4 weeks. New Hampshire DOT anticipates that the work will be finished in late summer 2004.

New Jersey Goes Precast for Victory Bridge

The new Victory Bridge, which carries Route 35 over the Raritan River, connecting Perth Amboy and Sayreville, NJ, was designed with a record-setting 134-meter (440-foot) main span—the longest precast cantilever segmental construction in the United States. The long-awaited project will relieve congestion in the region, replacing the aging swing bridge with its no shoulders and four narrow travel lanes. The new fixed structure will be high enough to accommodate marine traffic.

To reduce the construction time, New Jersey DOT (NJDOT) selected the segmental precast construction method for both the superstructure and substructure. The department estimates that by using this type of approach, it can reduce the duration of construction by at least 1 year. By employing segmental precast elements, NJDOT anticipates

Archived

saving millions of dollars, based on life cycle cost analyses. The new bridge will carry two 3.7-meter (12-foot) travel lanes in each direction with shoulders on each side and a sidewalk. Construction work began in February 2003 and should be complete by February 2006.

New Mexico Employs Creative Alternatives to Cash Incentives

Reconstruction of the I–25 and I–40 interchange in Albuquerque, NM, would require construction or rehabilitation of 55 bridges and 177 kilometers (110 lane miles) of roadway. Lacking viable alternate routes, the New Mexico DOT (NMDOT) had to complete the project while traffic continued to use the roadway.

The original interchange was designed in 1967 to support 40,000 vehicles per day. At the time of its reconstruction, however, the facility was severely overutilized with an estimated 300,000 vehicles using the interchange. Congestion resulted in an average of 1.7 crashes per day with a negative economic impact estimated at about $12 million annually. The project enhanced the level of service and reduced the accident rate on the most heavily traveled interchange in the State. NMDOT estimates that the new interchange will benefit the Albuquerque economy by approximately $1 billion over its first 10 years. The public benefited from reduced travel time, enhanced safety, and environmental improvements.

To minimize disruption to the community, the agency decided to reconstruct the interchange under a single contract with incentives to keep the construction time under 2 years. With little money available for cash incentives, NMDOT offered the contractor innovative incentives, such as access to excess right-of-way if the project was finished ahead of schedule. NMDOT purchased an 8.5-hectare (21-acre) parcel that included about 1.6 hectares (4 acres) of required right-of-way, with the remainder used as a staging area during construction. Since construction was substantially complete before the contract calendar date, the contractor received the deed to the remaining 6.9-hectare (17-acre) parcel. Ultimately, several tracts of land owned by NMDOT and determined to be excess to future highway needs were transferred to the contractor in lieu of cash incentives.

To minimize the impact on traffic, the project team used progressive techniques, such as segmental bridge construction, and established a traffic surveillance system and incident response program for the construction area.

Through close contact with the media during the project, the department cultivated public support by keeping motorists aware of potential delays. In the end, the incentives and careful management paid off: The completed interchange opened to traffic in May 2002, after only 23 months of construction.

New York Uses Precast Decks on Gowanus Expressway

In 2001, the New York State DOT (NYSDOT) replaced approximately 20 bridge spans on the Gowanus Expressway in New York City. After large-scale patching work failed to reduce deterioration of the existing decks in this section of the expressway (I–278) viaduct, NYSDOT determined that full deck replacement with precast panels offered an economical solution.

During weekend closures, the agency installed 3,716 square meters (40,000 square feet) of precast deck panels. The innovative panels consisted of a fabricated steel grid (the bottom portion) and a reinforced concrete slab (the upper portion). The top portion of the main bearing bars of the steel grid extend upward into the reinforced concrete component and act as shear connectors, assuring internal composite behavior. Advantages of this design include light weight, rapid construction, and efficiency of overall structural design. The project was completed in February 2002.

North Carolina Speeds Up Highway Delivery Using Design-Build

U.S. 64 between Wendell and Raleigh, NC, is a heavily congested commuter route and primary east-west highway that currently carries between 45,000 and 65,000 vehicles per day. The Knightdale Bypass in Wake County will route traffic around Knightdale, reducing travel time between Wendell and Raleigh by as much as 30 minutes.

"Because of its connection to eastern North Carolina and the daily congestion for commuters along this route, the Knightdale Bypass is a critical project for the region," says State Transportation Secretary

Archived

Lyndo Tippett. "By using the design-build process, we will be able to deliver this project about 3 years ahead of schedule."

The North Carolina DOT expects to complete the 15.5-kilometer (9.6-mile) project in early- to mid-2005. The total cost is about $131 million.

North Dakota Enhances Construction Using Fabrics

Although engineering fabrics, or geotextiles, are not new to construction, the North Dakota DOT (NDDOT) recently began using them to facilitate faster construction on urban projects with complex work phasing and congested work areas. The fabrics are used in lieu of more time-consuming subgrade preparations, allowing rapid placement of the granular base and leading to quicker pavement installation.

A successful example includes a $20 million urban project near the North Dakota Capitol grounds through a busy retail area of Bismarck. The project was completed in 2 years, with all of the work concentrated in half of the project's length each year. The engineering fabrics consist of polymeric filaments and are manufactured to specified strength and permeability standards. In this application, the fabric serves the combined purpose of reinforcing the material below the pavement and separating the natural earth material from the aggregate base supporting the pavement. Using engineering fabrics in combination with readily compacted aggregates to replace poor soils eliminates drying and reworking saturated soils and time-consuming compaction required when underlying soils are less than ideal for supporting pavement. The technique reduces the time between removing an existing pavement and placing a new pavement, particularly in urban areas where utilities and other obstacles preclude large-scale operations.

The agency also used the fabrics in projects near a traffic-congested section of I–29 in Fargo and at an interchange to a major regional shopping center. NDDOT project personnel are convinced that this acceleration technique is a significant time saver, adding quality to the pavement support system. "The process reduced the construction time for subgrade preparation by about 50 percent," says Adrian Fesser, construction coordinator for the Bismarck District Office of NDDOT.

Ohio Builds Bridges Faster, Smarter, Better

The Ohio DOT cut construction time by more than half on six bridge projects last year by using its strategic initiative: "Build Bridges Faster, Smarter, Better." Ohio has applied many bridge deck overlays in Cleveland and Cincinnati by closing traffic on major interstate routes after the Friday evening rush hour and opening the bridges before the Monday morning rush, thereby minimizing the impact on traffic during the rehabilitations.

"Ohio DOT is dramatically reducing the inconvenience of road closures for thousands of Ohio motorists by using innovative materials and contracting techniques," says Ohio DOT Director Gordon Proctor.

The department uses a variety of techniques to speed up the construction process, such as prefabricated materials, faster concrete curing methods, and contractor incentives and disincentives. The pilot program uses prefabricated concrete bridge members, which include deck slabs, barriers, and approach slabs that are post-tensioned together onsite. Other innovations include stay-in-place metal forms for the decks and single-span steel construction made continuous with concrete closure pours. Many bridge components can be manufactured offsite and "snapped" into place when crews are ready. In addition, steel forms can remain as part of the structure, eliminating the time needed to remove traditional wooden forms.

"If the program proves successful, it could have enormous implications for the reconstruction of our interstate system," Proctor says. "We've rebuilt about one-third of Ohio's interstate over the past decade, but two-thirds remain. If we can find ways to build these bridges faster, we can dramatically reduce delays for millions of motorists."

"Building bridges faster is more expensive," says Deputy Director Jack Marchbanks of Ohio DOT District 6, "however, Ohio motorists save millions of dollars because of the reduction in travel time delays and the associated fuel, vehicle, and productivity costs." The pilot program will last until 2006.

Oregon Invests in Bridge Delivery

In 2003, the Oregon legislature passed House Bill 2041, which provides $1.3 billion primarily for the replacement and repair of bridges on State highways. Through the Oregon Transportation Invest-

Archived

ment Act III State Bridge Delivery Program, a total of 365 bridges on the State highway system will be replaced or rehabilitated over the next 10 years. Most of the bridges are located on I–5, I–84, and other National Highway System routes. The program presents the opportunity to showcase alternative delivery methods and innovative technologies and materials.

"Accelerated design and construction techniques are crucial to the timely replacement of these deficient bridges," says FHWA Oregon Division Administrator David Cox. "These techniques will allow the Oregon DOT to minimize the negative safety and economic impacts due to out-of-service and restricted service bridges."

South Carolina Constructs New Parkway

To relieve congestion along U.S. 17 in the Myrtle Beach area, SCDOT initiated the Carolina Bays Parkway project to provide nearly 38 kilometers (21 miles) of controlled-access, six-lane divided freeway on a new alignment between U.S. 501 and SC–9. A number of innovative contracting approaches were used to get this roadway built and opened to the public.

The parkway project consisted of laying asphalt pavement, building 25 bridges, and constructing five new interchanges. The project was developed using the design-build concept with right-of-way acquisition services also included in the contract. A best value/fixed budget proposal outlined the minimum project requirements and additional options. SCDOT set the fixed budget at $232 million. Funding was acquired through the South Carolina State Infrastructure Bank, established by the State in 1997 to provide loans and other financial assistance for major projects. Federal-aid participation was established using advanced construction to facilitate future debt servicing. The contractor accomplished the minimum project scope and all additional options within budget and 6 months early. The parkway was opened to traffic in December 2002.

South Dakota Reduces Impact of Bridge Launch At Rail Yard

In the city of Aberdeen, the South Dakota DOT constructed a 97-meter (318-foot) steel truss bridge on an embankment next to a rail yard. The department minimized interruptions to traffic on the 15 train tracks to less than 16 hours while the truss bridge was moved into place. The contractor transported the 745-metric ton (820-ton) structure across the rail yard on rolling platforms, a launching technique that previously had been used on only one other project in the United States. If SDDOT had chosen to build a more conventional two-span structure, the impact on rail service would have lasted several months and involved relocating a significant amount of track.

In addition, rather than using a conventional painting system, SDDOT opted to "metalize" the steel used in the truss. Metalizing is a protective coating for steel with a low life-cycle cost. The department anticipates that the coating will last the life of the structure, which is estimated to be 75 years. Only minor maintenance may be necessary on the clear coating over the metalized steel, once or twice during the life of the structure. This steel protection option will reduce the potential for future maintenance activities that would affect rail and vehicle traffic.

The project began during the summer of 2000 and was opened to traffic in July 2002.

Tennessee Uses High-Performance Concrete for Bridge Construction

The Porter Road Bridge and Hickman Road Bridge, spanning State Route 840 in Dickson County, TN, both feature precast prestressed concrete girders and cast-in-place reinforced concrete deck slabs. The structures are jointless with integral abutments. This construction results in first-cost savings by avoiding expensive expansion joints and long-term maintenance costs. The Porter Road Bridge was completed in May 2000, and the Hickman Road Bridge was completed a few months later, in September 2000.

The Tennessee DOT used high-performance concrete in the pretensioned girders and reinforced deck slab. Coupled with jointless construction, the girders and deck are monolithic with the abutment wall, and the deck slab is continuous over the intermediate bent. The agency expects this combination of materials and structural system to result in dramatic short- and long-term benefits due to the greater strength and durability of high-performance concrete. Components of the bridges were instrumented to record their performance during all stages of construction and service.

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Texas Chooses Precast for Bridge over Lake Belton

The Texas DOT is working on a $20 million construction project to carry State Highway 36 over Lake Belton. The job includes removing the existing structure and constructing dual bridges.

"Using precast bridge caps, rather than cast-in-place, for the substructure, facilitates rapid and efficient construction," says David Hohmann, bridge design engineer at the Texas DOT. "In addition, the quality of the finished concrete products will be improved compared to cast-in-place products, especially considering the logistics of working out in the middle of a lake."

The project is 50 percent complete, with one half of the ultimate configuration already carrying traffic. The remaining half should be finished in summer 2005.

Utah Uses Design-Build Contracts for Traffic Signal Projects

The Utah DOT recently became one of the first State DOTs to use design-build contracting as a procurement method for traffic signal projects.

In February 2003, UDOT issued a request for qualifications to create a pool of design-build teams for these types of projects. The teams selected for the pool are thereby prequalified to submit proposals to design, construct, or modify warranted traffic signal projects throughout the State.

UDOT continuously studies intersections for crash trends and traffic volumes. When a specific intersection reaches the threshold to warrant a signal installation, the department now can select a contractor from the pool to begin work immediately, completing work in a shorter time than with traditional contracting methods.

"This dramatically reduces the time between when a signal is warranted and when it is turned on," UDOT Initiative Contracting Engineer Bob Dyer says. "It can save us up to 8 months over traditional contracting methods."

Dyer also notes an unexpected benefit from using design-build contracting on traffic signals: avoiding utility relocations that otherwise would have taken place if traditional contracting methods had been used. "This is saving taxpayers and utility users' money while helping us get jobs done faster," Dyer says.

UDOT is using a best-value selection process to choose the design-builder on a project-by-project basis. Two signals have been completed already, with four more currently under construction.

Virginia Widens Bridge Over York River

The George P. Coleman Bridge carries Route 17 over the York River in Yorktown, VA. In October 1993, the State of Virginia awarded a $72.7 million contract to widen the existing 1,143-meter (3,750-foot) two-lane bridge to four lanes using the existing substructure. The original bridge was 9.5 meters (31 feet) wide with no shoulders, and the new structure would be 23.6 meters (77 feet) with full shoulders.

The new bridge was built to improve traffic flow across the York River. The original structure, built in 1952, was designed to carry only 15,000 vehicles per day. By 1986, it was carrying 27,000 vehicles per day, and the Virginia DOT projected the number to grow to 43,000 by 2015. VDOT considered 17 solutions, but selected the widening project as the best in terms of cost, environmental impact, and meeting current and future traffic demands.

Construction included replacing six truss spans approximately 774 meters (2,540 feet) long. Innovative technologies employed in the project included state-of-the-art construction methods, truss spans constructed offsite 48 kilometers (30 miles) downriver at the Norfolk International Terminal and floated to the bridge site on barges with specialty support towers, and lightweight concrete used for the deck to minimize the dead load on existing piers.

These features reduced the time to replace the trusses by 36 days, or 60 percent, and resulted in a 27 percent cost savings. The project marked the first time a bridge had been floated in already prepared to carry traffic. The conventional method of floating only the steel trusses, placing the deck and the barriers on the bridge at the site, and using a temporary floating bridge to handle traffic would have cost VDOT an estimated $15.2 million.

The contract documents allowed two 12-day periods to swap out the old truss spans with the new ones. In May 1996, the contractor completed the swap and restored the bridge to full use in 9 days. The department dedicated the structure on August 2, 1996, after the approach spans were reconstructed and the toll facilities were completed.

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Washington State Rolls Bridge into Place

In November 2003, the Washington State DOT (WSDOT) completed the NE 8th Street/I–405 Bridge in Bellevue, marking the completion of the $16.4 million project after 18 months of construction—2 months ahead of schedule. The wider bridge over Interstate 405 makes it easier for commuters and visitors to get in and out of downtown Bellevue on the highway.

The project consisted of replacing the old bridge with a structure 10.7 meters (35 feet) longer and 0.9 meter (3 feet) higher to accommodate widening I–405. An innovative design for the new bridge called for half of the structure to be built in a temporary location and rolled into its permanent position. Conventional reconstruction would have taken the bridge out of commission for up to a year or reduced its capacity by half for even longer. Instead, construction caused relatively few disruptions to area drivers, with most closures limited to nights and select weekends. The contractor moved the 1,996-metric ton (2,200-ton) structure into place in about 12 hours.

Benefits include a wider, safer bridge with more lanes of traffic, space for widening I–405 in the future underneath the structure, and new ramps at a location just south of the bridge that improve downtown access for carpools, vanpools, and buses.

Washington State Rehabs Lewis and Clark Bridge

When upgrading the Lewis and Clark Bridge over the Columbia River between Longview, WA, and Rainier, OR, WSDOT committed to a tight construction window to minimize the impact on the traveling public. Rather than closing the bridge entirely, WSDOT shut it down from 9:30 p.m. to 5:30 a.m. nightly for 120 nights.

To replace the deck panels, the contractor used an innovative approach—a large specialized transport device that helped remove the old deck panels and deliver the new ones. Benefits to the public include leaving the bridge open for normal daytime traffic, which is important due to the bridge's close proximity to the Port of Longview. At a cost of approximately $25 million, the redecking project will extend the life of the Lewis and Clark Bridge for 25 years. WSDOT expects to complete the project by late spring 2004.

West Virginia Uses FRP Decks for Bridge

The West Virginia DOT replaced the existing structurally deficient Howell's Mill Bridge in Cabell County with a superstructure using 727 square meters (7,833 square feet) of fiber-reinforced polymer (FRP) deck on weathering steel beams. Carrying County Route 1 over Mud River, the bridge is a two-span structure 74.5 meters (245 feet) long and 9.9 meters (32.5 feet) wide.

Completed in late July 2003, the project demonstrated the use of FRP technology on a larger-scale project on a secondary route with significantly higher average daily traffic—3,400 vehicles per day. The site conditions required serious hydraulic considerations, given that the existing structure's roadway is submerged during flood events. By employing a slight change in grade and using the lightweight FRP deck to reduce dead load and achieve a minimal structure depth, WVDOT now has a structure capable of withstanding a 100-year storm event.

"The FRP decks are installed easily," says John Bargo, assistant bridge engineer at the FHWA West Virginia Division, "resulting in a shorter construction time, thus reducing delay and making the replacement structure available to the public much quicker." With the application of this innovative technology, WVDOT has provided the public with a longer lasting service life for the replacement structure.

Wisconsin Plans Marquette Interchange

The planned Marquette Interchange in downtown Milwaukee will replace deteriorated structures and improve safety and traffic operational characteristics at the junction of I–43, I–94, and I–794. The estimated cost of the project is $810 million.

Design and construction contracts will provide maximum opportunities for small businesses and disadvantaged enterprises. The project also will employ innovative technologies, such as high-performance steel and concrete to ensure a design life of more than 75 years. The project will be constructed in 4 years, between 2004 and 2008, and two lanes of through traffic will be open in the cardinal directions during construction.

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A World of Opportunities

This brief review of past, present, and future highway projects demonstrates the viability of employing innovative technologies programmatically, rather than sporadically, across the country, from the icy North to the tropical South, and from downtown urban areas to rural America. Money is not the deciding factor. The key ingredient is the will and determination of the design and construction teams to make the projects responsive to the needs of the public, whether that means completing construction faster or setting up a shuttle bus service to help travelers get around during construction. The tools are out there—now is the time to embrace them.

Kathleen A. Bergeron is a marketing specialist in FHWA's Office of Infrastructure. She has 27 years of experience in all aspects of marketing, including market research, public relations, and advertising. Her experience includes working for major consumer products corporations, a market research company, consulting engineering firms, and State and Federal transportation agencies.

Reprinted from *Public Roads,* May/June 2004.

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QUALITY ASSURANCE

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The Road to Quality Assurance

Learn the basic elements of a statistically-based quality assurance program for highway projects with the Federal Highway Administration's (FHWA) National Highway Institute (NHI) course on Materials Control and Acceptance-Quality Assurance. The course features an introduction to quality management and quality assurance. Participants then learn techniques for collecting, organizing, analyzing, and interpreting materials data, as well as assessing the strengths and weaknesses of process control and acceptance plans. The course also provides an introduction to risk.

The course is available in both a 4.5-day version (Course No. FHWA-NHI-134042) and a 2-day condensed version (Course No. FHWA-NHI-134042A). Topics covered include:

- Sampling theory.
- Organization of data.
- Analysis of data.
- Sources of variability.
- Process control.
- Acceptance plans and risks.
- Percent Within Limits acceptance plans.
- Implementation.

Among the skills participants will gain are the ability to describe necessary forms of data organization; identify population and sample means, standard deviation, and coefficient of variation; indicate sources of variability and how to use precision and bias statements; explain process control plans; identify the elements of acceptance plans; and identify procedures for verifying contractor tests used in acceptance decisions.

The course is designed for Federal, State, and local highway agency engineers in materials, construction, research, and other highway fields. The target audience also includes technicians involved in specification development and laboratory and field testing of highway materials. The course has a minimum class size of 20 and a maximum of 30. The fee is $600 per participant for the 4.5-day class and $270 for the condensed course.

To schedule the course, complete the "On-Site Course Request-Form 1530" at www.nhi.fhwa.dot.gov/registration.asp. For more information on the course content, contact Michael Rafalowski at FHWA, 202-366-1571 (email: michael.rafalowski@fhwa.dot.gov). For more information on scheduling a session, contact the NHI Training Team, 703-235-0534 (email: nhitraining@fhwa.dot.gov). A course description for the 4.5-day class is available at www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=102. The course description for the 2-day class can be found at www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=1208.

Reprinted from *Focus*, April 2006.

Archived

Percent Within Limits

The Quality Measure of Choice

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Meet the new quality measure of choice. Now available from the Federal Highway Administration (FHWA) is a 1-day introductory workshop on Percent Within Limits (PWL). As the workshop demonstrates, PWL is not just business as usual. "Generally the highway industry does not use an accept/reject model for evaluating contractors' work," notes Jim Walls of FHWA. "Rather highway agencies accept what is produced and pay accordingly, using payment systems that have incentives and disincentives." In contrast, the PWL model encourages highway contractors to produce consistent quality work and then rewards that work by tying payment to a statistically valid measure of quality.

The PWL workshop debuted February 8, 2006, in Raleigh, North Carolina. The workshop provides an overview of quality measures in general, details on how PWL works, and specifics on computing PWL. Also covered are payment issues and implementation steps and resources. Hands-on exercises give participants the opportunity to compare and contrast quality measures and compute PWL for sample materials data. A refresher module on basic statistical concepts is also included, covering such topics as probability, standard deviation, and sample size. The workshop is designed for State highway agency and FHWA division personnel responsible for developing and overseeing quality assurance specifications, as well as pavements and materials engineers.

More than 20 staff from the North Carolina Department of Transportation (NCDOT) attended the workshop. "There is a lot of interest in learning more about PWL, but also a lot of questions," notes Cecil Jones, State Materials Engineer for NCDOT. "PWL gives you a mathematical way to evaluate quality, but we have to make sure it's implemented in a way that's user friendly," says Shannon Sweitzer of NCDOT.

Quality measures for roadway projects are designed to obtain a more uniform product, increase service life, reward contractors for excellent work, and ensure that payment is appropriate to the product received. "With PWL, we're focusing on the degree to which a product or service conforms with a given requirement," says Ewa Flom of FHWA. Using PWL, a State can set specification limits and then determine the acceptable quality level for a job, which is the PWL value at which the contractor should receive 100 percent payment, and the rejectable quality level. The rejectable quality level is the PWL value at which the material or construction is unacceptable. Specification limits should be based on expected performance and contractor capabilities, and linked to life-cycle costs.

"PWL is a more efficient quality measure, allowing quality to be assessed with the lowest number of tests," says Walls. And unlike such quality measures as computing an average from material samples, PWL captures both the mean and standard deviation in one measure. This encourages contractors to produce a more uniform product.

To use PWL, material is sampled and tested and then analyzed statistically to determine the total estimated percentage of the lot that meets the specification. This is the PWL estimate. A PWL of 98.3, for example, means that 98.3 percent of the material meets the project specification. The workshop covers possible pay plans that can then be used, including stepped, continuous, and multilinear plans.

The workshop concludes by looking at challenges that have to be addressed when implementing PWL, including the need to define goals and expectations, understand best practices, reach agency consensus, and get top management and industry support. Resources available to assist with implementation include such FHWA publications as *Optimal Procedures for Quality Assurance Specifications* (Publication

No. FHWA-RD-02-095) and *Evaluation of Procedures for Quality Assurance Specifications* (Publication No. FHWA-HRT-04-046). These publications are available online at www.fhwa.dot.gov/pavement/pub_listing.cfm.

"The workshop was a good introduction to PWL. It enabled us to learn more about PWL and what it is all about," says Wiley Jones of NCDOT. On the day following the workshop, some NCDOT staff met with Dennis Dvorak of FHWA's PWL team to more specifically discuss applying PWL in North Carolina. "We went over practical guidelines for using PWL, such as how to set up limits and what to look for," says Randy Pace of NCDOT. "It gave us an opportunity to ask questions and get more specific examples. There is a lot of interest in learning more about PWL." North Carolina is now looking at scheduling another PWL workshop.

For more information on PWL or scheduling the workshop in your State, contact one of the FHWA PWL team members listed below. The PWL team members are also available to provide technical assistance in conjunction with the workshop.

FHWA PWL Team

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Reprinted from *Focus,* March 2006.

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A Brief History of Highway Quality Assurance

by Richard M. Weed

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One of the nation's most valuable assets is the network of roads and bridges linking suppliers of goods and services with customers. The nation's wellbeing depends on the highway system's condition, which in turn relates to the quality of construction.

Highway quality assurance has evolved over approximately four decades and encompasses all the programs and procedures for controlling and accepting construction quality. For the most part, the procedures in use today are fair and effective, but that was not always the case. As a former statistical engineer with the New Jersey Department of Transportation (DOT), I spent most of my career in quality assurance; following are some of the more important lessons learned.

Real-World Variability

The first of these lessons occurred while I was studying for a civil engineering degree. The lesson was taught not by one of my professors, but by a highway inspector who had few academic credentials. I was working in the summers on highway construction for New Jersey DOT when one of the inspectors had an interesting idea: "Let's send two identical samples to the department laboratory to see if they come out the same."

We carefully prepared two samples as nearly alike as possible and sent them to the laboratory. I do not recall the exact results, but they differed considerably more than we had expected. That was my first exposure to the real world of variability, and I sensed that this must be an important aspect of engineering.

Today we understand that there are several possible explanations for differences between tests of identical samples. Maybe the samples were not as identical as we thought; maybe the samples were handled differently during transportation; or maybe the samples were tested by different operators, or on different testing equipment, or on different days. But despite the potential sources of variability, samples of this type are used routinely to make important decisions about the acceptability of the construction items they represent. If this ever-present variability causes substandard work to be erroneously accepted, performance problems will arise that are likely to prove both costly and inconvenient. If satisfactory work is mistakenly rejected, completion of the project is delayed, the contractor is treated unfairly, and the result may be increases in future bid prices. Obviously, we need to minimize both types of mistakes.

Road Test Results

At roughly the same time I became acquainted with the realities of variability, the highway profession was learning a similar lesson from the American Association of State Highway Officials (AASHO) Road Test. This elaborate experiment alerted everyone that highway construction was far more variable than anyone had realized and, in some cases, was of lesser quality than anyone had recognized.

The reports from the AASHO Road Test used statistical measures to describe construction quality, and a few engineers saw that these same measures might offer a better way to specify what was desired than did the materials-and-methods specifications then in use. Not only would a statistical approach afford greater freedom to the construction industry to use its considerable skills and innovative abilities to achieve the desired results, but the approach also would provide a valid, quantitative way for highway agencies to judge the acceptability of the finished product.

The approach also would offer legal advantages, because in some cases, courts of law had not allowed highway agencies to reject defective work over which the agencies had exercised primary control

via materials-and-methods specifications. Another advantage would be the creation of valid databases that eventually could improve understanding of the relationships between construction quality and ultimate performance.

This new approach of basing construction specifications on statistical concepts clearly was a win-win situation for all concerned. As engineers gained familiarity with statistical techniques, the use became more frequent and more effective. Growing pains were inevitable, but these early efforts turned out well enough that within a few years many other highway agencies had followed suit.

Analyzing the Risks

One of the most significant realizations from this early work was that the analysis of operating characteristic (OC) curves and of expected payment (EP) curves was an indispensable part of statistical quality assurance. Only through the study of these curves can two critical risks be known and controlled at suitably low levels: the highway agency's risk of accepting defective work, and the contractor's risk of having good work penalized or rejected.

This offers both technical and diplomatic advantages. The correction of faulty specifications in the office before reaching the field greatly increases the likelihood of making good acceptance decisions. Assuring that statistical specifications perform correctly and fairly greatly improves the working relationship between the highway agency and the construction industry.

Statistical Quality Measures

The first specifications of this type applied simple statistical measures, often the mean—or average—of the test values. As more construction data became available for analysis, engineers realized that the mean by itself was not always an adequate predictor of performance. Two lots of material having the same mean might have markedly different levels of variability and, consequently, substantial differences in the amounts of substandard material and in the expected levels of performance.

The next step was to look for statistical quality measures that would take variability into account. The moving average was out—it was as insensitive as the mean was to variability. In addition, the moving average was influenced by adjoining lots of material, making any type of risk analysis extremely difficult.

A few agencies tried average absolute deviation, which has never been studied thoroughly as a formal statistical measure and is not well suited for singlesided specifications for which a unique target value cannot be defined. The conformal index also was proposed, but the drawbacks are essentially the same as those of the average absolute deviation.

This left as the logical choices percent defective (PD) and percent within limits (PWL)—which are different representations of the same thing. PD/PWL is a standard statistical measure, extensively studied, known to be an unbiased estimator, capable of handling single-sided and double-sided applications, and with published tables for use. For these reasons, PD/PWL continues to have the strongest intuitive appeal to most writers on statistical quality assurance.

Bonus Provisions

Another key milestone in the development of highway acceptance procedures was the advent of bonus provisions. The earliest statistical specifications either paid full price or assessed some degree of pay reduction, depending on the deficiency in quality. Highway engineers eventually realized that if withholding payment for substandard work made sense, offering some degree of monetary incentive for superior work also made sense. The idea was to encourage and compensate contractors whose attention to quality control produced work that substantially exceeded the specified levels of quality and, as a result, could be expected to provide above-average performance.

Several arguments support an incentive approach. Once OC/EP curve analyses became more common practice, some degree of bonus provision was recognized as necessary for the long-term average pay factor to be 100 percent for work exactly at the level defined as acceptable. The natural variability of statistical measures often produces quality estimates that are either too low or too high. Bonus provisions allow the resulting underpayments or overpayments to balance in a way that turns out to be fair and equitable.

Other benefits of bonus provisions include motivation for higher quality work, improved relations with the construction industry, and the likelihood that better contractors more often will be the successful bidders—because contractors more assured of receiving bonus payments can afford to bid lower. Because of these benefits, a substantial majority of

Archived

highway agencies now use bonus provisions in one form or another.

Performance-Related Specifications

A goal in highway specification writing is to relate basic engineering properties—for example, the resilient modulus of pavement—directly to performance, so that specifications only state appropriate levels of appropriate properties. That goal remains elusive, however, and efforts have focused on developing performance-related specifications (PRS) based on mathematical models linking quality characteristics—such as air voids in asphalt concrete or the compressive strength of portland cement concrete—or statistical quality measures, such as PD or PWL, to performance and longevity. Typically, these specifications include pay schedules developed through life-cycle cost analysis.

PRS developmental efforts have produced a dichotomy of approaches. On the one hand, highly complex national studies have produced sophisticated computer programs like HMASPEC and PCCSPEC, based on mechanistic design principles, life-cycle cost analyses, and various decision-making processes. On the other hand, a few state transportation agencies, including New Jersey DOT, are engaged in grassroots efforts to use their own data to create simplified mathematical models with the same underlying scientific principles.

The methods developed by the national studies offer the potential for greater precision and accuracy, but at the expense of considerably greater data requirements and complexity. The grassroots models are more empirical, but their simplicity and ease of being tailored to local conditions make them attractive from a practical standpoint. States that would like to convert statistical specifications to actual PRS will have to decide which of the two profoundly different approaches to take. The optimal approach may lie somewhere between these two extremes.

Simple but Scientific

Much has been accomplished in the field of highway quality assurance, but much remains to be done. A slight variation of the KISS rule has served New Jersey DOT well: Keep It Simple but Scientific. The guidance may be useful to other agencies as they continue to advance the state of the art of PRS.

In other words, start with the simplest approach that makes scientific sense, and switch to something more complex only if there is evidence or data showing that the simple method is not working. As a statistical practitioner always concerned about the accumulation of error in any complex system, I advocate this practical approach for designing any engineering process.

The author, who retired from the New Jersey Department of Transportation in 2002, is a full-time consultant based in Trenton. He is an Emeritus Member of the TRB Management of Quality Assurance Committee.

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Maintenance Quality Assurance

Learning from Your Peers

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Adjusting highway agency budget allocation models to include roadway condition data was one of the challenges for highway maintenance managers raised at the first National Maintenance Quality Assurance Peer Exchange Conference held in Madison, Wisconsin, from October 11–13, 2004. Thirty-six States and Canadian provinces and three counties were represented at the conference, as well as the U.S. Forest Service and the University of Wisconsin. The conference was sponsored by the Federal Highway Administration (FHWA), the Midwest Regional University Transportation Center (MRUTC) at the University of Wisconsin, the American Association of State Highway and Transportation Officials (AASHTO) Highway Subcommittee on Maintenance, and 21 State departments of transportation. As the first peer exchange of its type, it offered participants a rare chance to network and compare best practices with others in their field.

"Maintenance quality assurance programs have been growing over the last 20 years, and the people running them don't have many peers in their organization," says Alison Lebwohl of the Wisconsin Department of Transportation (DOT) and chair of the conference. "When you have a question, you don't have anyone to bounce information off of."

Maintenance quality assurance (MQA) programs help measure and report on the condition of highway assets, linking results to budgets and providing managers with program measurements. Highway program managers are often struggling to measure their programs in meaningful ways. "If you invest 'x' dollars, you've got to be able to prove you've got a better program," notes Jason Bittner of MRUTC. "What does measuring the tons of salt on the roadway give you? It doesn't really give you anything. It doesn't tell you about the resulting condition of the roads."

Keynote speaker Carlos Braceras, deputy director of the Utah Department of Transportation and chair of the AASHTO Highway Subcommittee on Maintenance, noted the importance of carefully analyzing what matters most to customers and then reallocating funds to improve levels of service. "Our customers will be asking us to do more and more, and we will not be getting more resources in the future," Braceras said. "We will need to make good decisions on what we are spending our money on, and we need to make good decisions about what we are not spending our money on."

Participants met in breakout sessions to discuss their top concerns and issues. These included developing a budget allocation model that is not only based on history, but also incorporates MQA data; determining how to use conditions and dollars spent to predict outcomes; developing meaningful and consistent performance measures for winter maintenance; integrating pavement management, maintenance management systems, and MQA; developing a set of frequently asked questions about

The first National Maintenance Quality Assurance Peer Exchange Conference offered participants a chance to compare best practices with others in their field.

MQA statistics, with illustrative case studies; and developing a guide to highway maintenance that looks at why it matters, what it costs, and what happens when it is not done.

Participants also shared their experiences and best practices. Larry Galehouse, Director of the National Center for Pavement Preservation in Okemos, Michigan, spoke about the value of pavement preservation programs. These programs combine pavement preventive maintenance, rehabilitation, and reconstruction into a single comprehensive strategy to improve the future long-term condition of the highway network. The mix of fixes helps optimize the use of available funds to meet network condition needs, producing a better return on the money spent. Using preventive maintenance treatments, such as micro-surfacing, chip seals, and slurry seals, allows highway agencies to postpone costly reconstruction or rehabilitation activities by extending the service lives of their original pavements.

Maintenance quality assurance (MQA) programs help measure and report on the condition of highway assets, linking results to budgets and providing managers with program measurements.

Topics discussed at the conference will be edited into a formal list of national priorities by the conference steering committee. The committee hopes that this list will be used to determine research projects and priorities. Missouri, for example, has already used information from the list to make research decisions, Lebwohl notes.

All presentations and conference materials are available in an online resource library (www.mrutc.org/outreach/mQA), and a listserv is also available for networking. For more information on the conference or MQA, contact Alison Lebwohl at 608-266-8666 (email: Alison.Lebwohl@dot.state.wi.us), or Jason Bittner at 608-262-7246 (email: bittner@engr.wisc.edu).

Reprinted from *Focus*, November 2004.

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PERFORMANCE STANDARDS AND PERFORMANCE WARRANTIES

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The Case for Performance Standards

by Cheryl Allen Richter

Ambitious, but achievable, expectations are the first step to improve safety, to reduce construction-related congestion, and to enhance quality.

What if the highway community were to gauge the success of a highway construction project not from the perspective of engineers and public officials, but from the perspective of highway users? What might standards for customer service in the areas of safety, construction-related congestion, and quality look like? What if the government agencies and contractors responsible for highway construction were to use customer-focused performance standards—standards addressing characteristics such as smoothness, noise, longevity, and congestion—to define the highway infrastructure without being prescriptive about how it is built? How might such standards contribute to achieving a highway community that is more focused on meeting the needs of users and more open to new technologies that can improve highway safety, reduce construction-related congestion, and enhance the quality of our highway infrastructure?

The Federal Highway Administration (FHWA) has identified customer-focused performance standards as one measure that could contribute to significant advancement in highway construction practices.

Specifications Versus Performance Standards

While specifications define or provide a recipe for getting to a specific final product, performance standards tell what level of performance is expected for that product and then leave it up to the targeted organization to work out how to get there. In essence, performance standards represent a step beyond end-result specifications. The primary benefit is that an organization is allowed to use its expertise and experience to come up with innovative ways of obtaining the desired performance, rather than simply doing what has always been done before.

Skeptics who doubt that performance standards can be used effectively might look at the relationship between the Federal government and the automobile industry. Although the Federal government does not dictate specifically how manufacturers build their cars, several agencies are involved with making sure those vehicles are designed and built to certain levels of performance.

For example, the National Highway Traffic Safety Administration is charged with maintaining crashworthiness standards, so the agency developed standards such as the frontal crash compliance test, which calls for a 48.3 kilometers per hour (kph), or 30 miles per hour (mph), impact into a rigid, fixed barrier. The agency also coordinates the Corporate Average Fuel Economy (CAFE) standards, which dictate the average level of fuel efficiency that an automobile manufacturer's vehicles must maintain. That standard is currently 11.7 kilometers per liter (27.5 miles per gallon) for passenger automobiles and 8.8 (20.7) for light trucks.

The U.S. Environmental Protection Agency (EPA) regulates standards for motor vehicle pollution. As EPA's Office of Mobile Sources indicates on one of its Web sites (http://www.epa.gov/otaq/invntory/overview/solutions/vech_engines.htm), EPA standards direct how much pollution autos may emit, but automakers decide how to achieve the pollution limits. The emission reductions of the 1970s came about because of fundamental improvements in engine design, plus the addition of charcoal canisters to collect hydrocarbon vapors and exhaust gas recirculation valves to reduce nitrogen oxides. Car companies are left to determine how best to meet the standards while delivering the best value to their customers. The result is an automobile industry that is responsive to the needs of the public, yet free to make use of innovation and imagination to compete

Archived

in the marketplace. The standards actually appear to drive quality up!

The highway infrastructure analog to the three performance standards for automobiles—crashworthiness, CAFE, and emissions standards—might be safety, quality, and congestion resulting from construction. As with the auto world, in highway construction, performance standards should not spell out a recipe for building a section of highway or a bridge, but rather give the contractor the levels of safety, quality, and the like that are expected, and then allow the contractor to use its own abilities to meet that challenge. Another important parallel is that it would not be sufficient to meet only one or two of the standards; safety, quality, and congestion minimization are all necessary to customer satisfaction.

Finally, although the focus here is on construction, it must be recognized that just as the production of safe, fuel-efficient, low-emissions automobiles begins well before the manufacturing process starts, highway construction projects that meet demanding standards for safety, construction-related congestion, and quality begin with plans and designs that consider the needs and behavior of highway users in addition to the host of issues and factors that affect the highway construction process and the quality of the end product.

Why Performance Standards?

The most obvious rationale for performance standards is reflected in the preceding discussion of auto safety, CAFE, and emissions standards. They work! Automobiles coming off the assembly line today are safer and more fuel efficient and produce fewer emissions than those built a decade or two ago, not because someone dictated how they should be built, but because the desired end result was defined, and the industry was given the freedom to innovate and figure out how that result could be achieved. Consequently, lives and fuel have been saved, and the air that Americans breathe is cleaner than it would otherwise be.

The success of the auto safety, CAFE, and emissions standards demonstrates that such standards are highly effective drivers of change. Faced with this success, why would the highway construction community not want to adopt a proven approach to addressing the pressing challenges of highway construction? Why not establish specific targets to drive improvements in safety, construction-related congestion, and quality?

Most would agree that making highways safer, reducing construction-related congestion, and improving the quality of our highway infrastructure are laudable and appropriate goals. But what—specifically—do these goals mean? To be meaningful, lofty goals such as these must be translated into specific targets—performance standards—that clearly define and communicate expectations for improved safety, reduced construction-related congestion, and improved quality. A performance standard can serve not only as a "target to shoot at" but also as a benchmark against which success can be assessed. As such, these standards can provide a basis for gauging the value of specific tools, materials, and technologies, and construction or contracting practices, and the success, strengths, and weaknesses of individual construction projects or groups of projects.

A side benefit of performance standards is that they bring the construction contractor into the customer satisfaction equation. Rather than simply giving a contractor a set of specifications and waiting for the contractor to build a highway in an information vacuum, the owner agency focuses the contractor's efforts on specific customer-related needs, such as minimal traffic disruption, speed of completion, smoothness level, quiet level of ride, or increased level of safety. Thus, the contractor and owner agency become a team aimed at satisfying the needs of the customer, rather than simply getting a road built.

Performance Standards in Practice

Although the proposed role for performance standards goes well beyond current highway construction practice, performance standards for highway construction are nothing new. Because pavement smoothness is widely recognized as important from a standpoint of both user satisfaction (no one likes to drive on a rough road) and long-term performance (because smooth roads last longer and are often of higher overall quality than rough roads), performance standards for pavement smoothness have seen widespread use. Most State highway agencies use smoothness specifications of one form or another. These specifications establish target values (standards) for smoothness as measured using standard engineering test methods that have

Archived

been related to user perceptions. Many include incentives and/or disincentives to encourage achievement of the high levels of smoothness that result in reduced operating costs for highway users and reduced maintenance costs for the owner agencies. Current performance standards for smoothness and the results obtained with them are illustrated by examples from Arizona, Virginia, and Kansas.

Arizona

For new construction, Arizona has a target International Roughness Index (IRI) value of 41, with smoothness expressed as IRI in inches per mile. Incentives are earned for values below 38, and disincentives are assessed for values in excess of 48.

For rehabilitation projects, the target, incentive, and disincentive values vary as a function of highway type, the nature of the work to be performed, and (in some cases) the smoothness of the existing pavement. Ranges are as follows:

- Target smoothness: 39 to 68
- Thresholds for incentives: 37 to 66 (target minus 2)
- Threshold for disincentives: 49 to 78 (target plus 10)

Removal and replacement (as opposed to other corrective action) is required for smoothness values that exceed the target plus 45.

Incentives Earned. In general, typical pavement smoothness incentives paid by the Arizona DOT average approximately $7,500 per lane mile or approximately $1.00 per square yard.

Typical or Average Levels of Smoothness Actually Provided. Average contractors in Arizona produce IRI smoothness values in the mid 30s. Some very good contractors consistently achieve IRI smoothness values in the low 30s, with substantial areas often in the 20s.

Virginia

Virginia has smoothness special provisions for new construction and maintenance resurfacing, with smoothness expressed as IRI in inches per mile. For new construction, payment of 100 percent is for an IRI between 55 and 70 inches/mile. Bonus payments are earned for achieving IRI values less than 55, and penalties are incurred for IRI values greater than 70, to a maximum of zero payment at IRI values greater than 160 inches/mile. Corrective action is required when the average IRI for a section exceeds 100 inches/mile.

For maintenance resurfacing, a maximum 10 percent bonus based on the AC surface cost is possible for interstate sections with an IRI less than 45 and for noninterstates with an IRI less than 55. Additionally, 100 percent payment is for interstates from 55 to 70, while noninterstates must have an IRI between 65 and 80 for 100 percent payment.

Unlike new construction projects, most resurfacing projects are tested prior to and after paving. These projects are either a straight overlay or a mill-and-replace. The before-and-after testing is used to determine the amount of improvement in ride quality. If the contractor is able to improve the quality by more than 30 percent, then the contractor is guaranteed 100 percent payment for ride.

Incentives Offered by These Specifications. For new construction, the contractor can receive an incentive of up to 5 percent based on IRI results. The amount of the incentive is based on the unit cost for all AC layers or the square yard unit cost for the PCC.

Maintenance resurfacing contracts allow up to a 10 percent bonus. This amount is based on the AC surface cost.

Typical or Average Levels of Smoothness Actually Provided. Virginia has been actively using a ride special provision since the late 1990s. Most of the ride data have been collected on maintenance resurfacing projects. With more than 150 projects in 2002, the average IRI on interstates was 60 inches/mile. For noninterstate routes, the average was 67 inches/mile on U.S. routes and 74 inches/mile on State routes. Over the last 6 years, the average IRI on the interstates has stabilized; the ride quality on noninterstate routes continues to improve. Analysis of the 2003 ride sites is underway.

In addition to improved ride quality, Virginia has seen other benefits through use of these special provisions. During the mix-design process, contractors are developing mixes that better balance mix production costs and level of effort to achieve good quality field placement. These mixes result in better ride, better density, less tendency to segregate, less permeability, and more liquid asphalt for durability. When the ride special provision is applied to the project, more attention to detail is given during the paving process through use of a materials transfer vehicle, continuous feed of material, no stopping of the paver, and proper rolling techniques. The use of

Archived

the ride special provision provides initial monetary incentives to the contractor and longer lasting pavements for the taxpayer.

Kansas

With smoothness expressed as profile index in millimeters/kilometer (mm/km), Kansas specifications, in general, require an average profile index of 475 mm/km or less per 0.1 km section as measured with a California-type profilograph, a wheeled instrument for measuring smoothness by amplification of any variations from the plane. For PCC pavements, a higher value of 710 mm/km is allowed for roadways with a posted speed of 45 miles per hour (mph) or less and ramps. For flexible pavements, an exception is made for ramps and acceleration and deceleration lanes, for which a profile index of 630 mm/km or less is required. In addition, PCC pavement areas within each section having high points with deviations greater than 7.5 mm and flexible pavement areas within each section having high or low points with deviations greater than 10 mm in a length of 7.5 meters are to be corrected regardless of the profile index. The full specifications may be found at www.ksdot.org/public/kdot/burconsmain/specprov/pdf/90m-0111-r10.pdf (PCC) and www.ksdot.org/public/kdot/burconsmain/specprov/pdf/90m-0039-r09.pdf (flexible pavements).

Incentives Offered by These Specifications. Pay adjustments are based on the average profile index determined for the sections prior to any corrective work such as grinding. If the contractor elects to remove and replace the sections (or overlay flexible pavements) to meet the smoothness specification, pay adjustments will be based on the average profile index obtained after replacement or overlay. See tables labeled "Schedule for Adjusted Payment—Flexible Pavements" and "Schedule for Adjusted Payment—PCC Pavements" for pay adjustment schedules.

Typical or Average Levels of Smoothness Actually Provided. Although some fluctuation has occurred from year to year, Kansas has seen a substantial increase in the percentage of pavements built with high levels of smoothness (0 to 240 mm/km for PCC pavements and 0 to 160 mm/km for flexible pavements).

Schedule for Adjusted Payment—Flexible Pavements

Average Profile Index (mm/km per lane per 0.1 km section)	Contract Price Adjustment (per 0.1 km section per lane)
110 or less	+$100.00
111 to 160	+$50.00
161 to 475	0.00*
476 to 630	0.00*

* Correct to 475 mm/km (630 mm/km for ramps, acceleration and deceleration lanes)

Schedule for Adjusted Payment—PCC Pavements

Average Profile Index (mm/km per lane per 0.1 km section)		Contract Price Adjustment (per 0.1 km section per lane)
(greater than 45 mph)	(45 mph or less and ramps)	
95 or less		+$760.00
96 to 160	240 or less	+$630.00
161 to 240		+$470.00
	241 to 400	+$310.00
241 to 285		+$240.00
286 to 475	401 to 710	+$0.00
476 to 630	711 to 1025	+$0.00*
631 or more	1026 or more	-$470.00*

* Correct to 400 mm/km (710 mm/km for 45 mph or less and ramps)

How Might Performance Standards Look?

In highway construction, "the devil is in the details," and so it is with performance standards for highway construction. Although the smoothness specifications discussed in the preceding paragraphs represent important and successful steps toward customer-focused performance standards, they address only one aspect of performance. A complete set of customer-focused performance standards would address not only smoothness (which might be thought of as one element of quality), but also safety, congestion, and other aspects of quality. Moreover, an effective set of customer-focused performance standards would be founded on extensive input and participation from stakeholders throughout the highway community. Criteria that might be considered in formulating performance standards include:

Archived

- Availability of a standard test procedure for the metric
- Feasibility of applying the performance standard within the context of highway construction projects
- Ability of the work performed to influence the characteristic measured by the metric
- Specificity of the standard to the desired outcome—improved safety, reduced construction-related congestion, or improved quality

To be truly effective, standards should be set at a level of performance well above average, but within the bounds of what has been achieved with current best practices and technologies. That is, they should require that agencies and contractors strive for excellence without setting a goal that cannot be achieved.

Several candidate performance standards are identified in the tables labeled "Possible Performance Standards for Safety," "Possible Performance Standards for Construction-Related Congestion," and "Possible Performance Standards for Quality." Identification of these candidate standards was guided, but not wholly driven, by the criteria outlined above. Identification of appropriate, nonprescriptive standards and performance measures for overall quality and longevity is especially challenging because the most obvious measures require long-term monitoring of performance. In practice, it may be appropriate to identify a small number of surrogate "quality indicators" in lieu of true quality standards.

Application of the Performance Standards

How might performance standards be applied in practice? A good place to start, after completing the development of a preliminary set of standards through dialogue with highway stakeholders, would be to apply them on some pilot projects that include the collection of data prior to, during, and after construction to support evaluation and refinement of the performance standards.

Customer-focused performance standards have the potential to be a key driver of innovation in the highway construction business. Such standards could establish elevated expectations for achievement in the areas of highway safety, minimization of

Possible Performance Standards for Safety

User Concern	Parameter	Measure and Standard
Travelers are able to navigate the work zone safely	Work Zone Safety	Work zone crash rate less than statewide average
	(Two options identified)	Work zone safety index (to be defined)
Highway construction workers are not injured	Worker Safety During Construction	Worker injury rate less than 7.7 injuries and illnesses per 100 full-time workers
Travelers are able to navigate the highway safely under both wet and dry conditions	Facility Safety After Construction	Reduction in fatalities and injuries as reflected in 3-year average crash rates, using preconstruction rates as baseline

Possible Performance Standards for Construction-Related Congestion

User Concern	Parameter	Measure and Standard
Avoid or minimize travel delays caused by highway construction	Travel Time	Less than 10 percent reduction in average speed, using 100 percent sampling
	Queue Length	< 0.5-mile stopped queue (speed less than 10 mph)
		< 1.5-mile moving queue (travel speed 20 percent less than posted speed)

Possible Performance Standards for Quality

User Concern	Parameter	Measure and Standard	
Ride is comfortable	Smoothness	IRI less than 0.80 m/km (pavements)	
		Profile Index Value < 10 inches per mile (bridges)	
Ride is quiet for drivers, passengers, and those adjacent to the highway	Noise	Close Proximity Method (CPX), A-weighted decibels (dBA)	94.0
		Intensity	97.0
The end product of the construction process was worth the inconvenience incurred to get it done	User Satisfaction with Construction Process and End Product	Customer satisfaction rating	

Archived

construction-related congestion, and highway quality, all of which are of vital importance to the users of the national highway system.

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The author would like to thank Lorenzo Casanova, Ken Davis, and Kirk Fredrichs of the FHWA Virginia, Arizona, and Kansas Divisions for gathering information for this article.

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Reprinted from *Public Roads,* May/June 2004.

Archived

Pavement Warranties Yield Innovation, Quality

Faced with staff and budget shrinkages and the need to increase pavement quality and life-cycle performance, some State highway agencies are finding that pavement warranties offer an alternative way to assure performance. These warranties guarantee the integrity of the product and the contractor's responsibility to repair or replace defects for a defined period.

The Indiana Department of Transportation (INDOT) started using warranties on asphalt pavements 7 years ago. The agency's goal was to encourage contractor innovation and at the same time compensate for a decrease in manpower for inspection and oversight. "We wanted to be able to do more with fewer people," says Dave Andrewski of INDOT. Indiana awards about two or three warrantied projects a year, with the warranties good for 5 years. The warranties are placed on very high traffic volume projects in conjunction with time incentives. This is done to ensure that the fast pace of construction that time incentives encourage still produces a high quality project for INDOT. The effort started with asphalt pavements but expanded last year to concrete with the construction of a warrantied pavement on I-65 in the southern part of the State. The warranty specifications were developed in concert with industry. Indiana is pleased with the results to date. "The projects are built faster and we get quality work and very smooth pavements," says Andrewski.

At the end of the 5-year warranty period, threshold values for International Roughness Index, surface deformation (rutting for asphalt pavements/scaling for concrete pavements), transverse cracking, longitudinal cracking, friction number, and joint sealant condition (for concrete pavement only) are measured. If the pavement meets those values at the 5-year mark, then INDOT is confident based on historical data that the pavement will be serviceable through its design life. To date, two asphalt pavement contracts have reached the 5-year mark and both have been accepted.

The Michigan Department of Transportation (DOT) started using warranties in 1996. While the agency started with materials and workmanship warranties, it has since expanded the warranty program to include performance warranties also. Performance warranties allow the contractor more flexibility in terms of materials selection, workmanship methods, and design decisions. "We started exploring warranties as a way to reduce oversight but still ensure that contractors are delivering the high quality product we need. It's also about getting contractors to take a long-term interest in pavement performance," says Steve Bower of Michigan DOT. "We're trying to get the contractors to have a high level of self awareness with regard to construction quality. It raises awareness about how workmanship and materials decisions can affect long-term pavement performance." From 1996-2002, the State let 473 preventive maintenance projects that had warranties and 131 rehabilitation projects. More than 90 percent of projects in the agency's 2002 Capital Preventive Maintenance (CPM) Program were warrantied, while more than 50 percent of 2002 reconstruction and rehabilitation projects included a pavement warranty.

CPM pavement warranties are for a 3-year duration and include treatments such as thin asphalt overlays, concrete patching, chip seals, and microsurfacing. Rehabilitation and reconstruction warranties are for a 5-year duration and include fixes such as new concrete and asphalt construction, hot-mix asphalt (HMA) overlays on repaired pavement, and HMA overlays on rubblized concrete pavement.

In December 2002, the DOT began work on a 19.3-km (12-mi) project on the M-6 Freeway Bypass in Grand Rapids that will have a 7-year performance warranty. "The contractor will have additional flex-

Archived

ibility with the mix design, more than would usually be given under the standard QC/QA approach," says Bower. Two more performance warranty projects will be let in March 2003, using the same specifications.

Michigan reports that its construction oversight costs have dropped since it started using warranties. The DOT has not yet seen a longer service life for pavements but it has observed more innovation on the part of contractors. Lessons learned have included the need to have a good pavement management system (PMS) in place. A good PMS is necessary in order to have the comprehensive pavement performance data that is needed for developing pavement performance measures and thresholds. Bower notes that the agency picked thresholds and performance levels that are attainable based on pavement management data from past projects. "It is imperative that you manage the risk for contractors or it will translate into higher bid prices," says Bower.

For more information on Indiana's warranty use, contact Dave Andrewski at INDOT, 317-610-7251, x. 212 (email: dandrewski@indot.state.in.us). For more information on Michigan's warranty program, contact Steve Bower at Michigan DOT, 517-322-5198 (email: bowers@michigan.gov). To learn more about pavement warranties in general, contact John D'Angelo at FHWA, 202-366-0121 (fax: 202-493-2070; email: john.d'angelo@fhwa.dot.gov).

Reprinted from *Focus*, January/February 2003.

Archived

Pavement Warranties

Learning from the European Experience

Archived

Does your road come with a warranty? Traditional U.S. construction contracts have typically required contractors to provide a project warranty for just 1 year following construction completion. Highway agencies are now increasingly requesting longer term warranty contracts on large asphalt paving projects, with the goal of improving pavement performance and reducing life-cycle costs. Four- and 5-year warranties are already common in Europe, where some highway agencies have been using them for more than 40 years. To learn more from Europe's experiences, a U.S. panel of Federal, State, and local government and industry representatives traveled to Spain, Germany, Denmark, Sweden, and Great Britain in September 2002 for a "European Asphalt Pavement Warranties Scan." The Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) jointly sponsored the scanning tour, under the guidance of the FHWA Office of International Programs and the National Cooperative Highway Research Program.

The scan was designed to review and document the policies and strategies used in Europe to determine risk assessment and administer warranty contracts. As the participants learned, all of the countries visited believe that warranties have improved the quality of their highway systems. "They're achieving a better quality product and a better relation with contractors," says scan co-chair John D'Angelo of FHWA. Specific items studied were:

- Methodologies used to determine risk assessment for the government agency and contractor;
- Methodologies for administration of warranty contracts;
- Methodologies to select criteria to account for traditional performance indicators of rutting, fatigue cracking, and low temperature cracking;
- Practices to maintain prescribed levels of smoothness and skid resistance;
- Criteria used in successful asphalt pavement warranties; and
- Pavement performance prediction tools.

Meetings were held with government agencies, academia, and private sector organizations. Participants also had the opportunity to visit sites where innovative asphalt warranty contracting techniques were being applied. "I found particularly interesting Europe's long standing experience with materials and performance warranties," says Steve Bower of the Michigan Department of Transportation. "These materials and workmanship warranties cover all types of road construction work, including pavements, bridges, roadway embankments, seeding and sodding, and pavement marking."

All of the countries visited use materials and workmanship warranties, which ensure that the contractor will build the pavement as specified by the owner and fix any defects resulting from the use of improper materials or inferior installation. Warranty periods vary, with Spain employing a 1-year warranty period, for example, and Germany using a 4-year warranty.

Three of the countries, Denmark, Sweden, and Great Britain, use performance warranties. This type of warranty covers the performance of the complete asphalt pavement, in addition to materials and workmanship, and allows for contractor innovation in mix design and/or material installation. All three countries have a 5-year warranty period. In addition to rutting, cracking, and durability, smoothness and friction are often measured as well.

All of the countries use a best-value procurement process instead of a low bid one. Under this procurement process, the contract is awarded based on technical and/or performance items, not just cost. The best-value criteria include safety features, inno-

The scanning tour panel meets with the government in Denmark, as well as industry representatives from Denmark and Sweden.

The scanning tour panel in Germany.

Archived

vation, and environmental impact. Denmark also considers the bidding of additional years of warranty as a best-value criterion. The host countries consider this best-value criteria to be critical to their warranty programs, as highway agencies must have greater confidence in contractors' ability to get the job done.

The European countries are also looking at alternative contracting as a way to increase innovation without creating a burden for highway agencies, which are increasingly short-handed. Two of these alternative contracting methods are pavement performance contracts (PPCs) and design-build-finance-operate (DBFO) contracts. PPCs extend performance warranties to cover a warranty period that is closer to the design life of the pavement. The contractor is responsible for designing, constructing, and maintaining the performance of the pavement at pre-specified levels. Maintenance can include anything from filling potholes to a complete mill and overlay of a section of pavement. All five countries are using or experimenting with some

form of PPCs, which have warranty periods of 11 to 20 years. The PPCs are being developed in close collaboration with industry.

Both Spain and Great Britain are using DBFOs to turn a small fraction of their highway network over to the private sector for long-term financing, operation, and maintenance. These DBFO contracts range from 25 to 30 years. Several factors are contributing to the use of the contracts, including a lack of public funding and the belief that private financing and maintenance can sometimes deliver a higher quality product.

Following its observation of the successful European warranty programs, the scan team's recommendations include:

- The Federal Government should consider requiring short-term material and workmanship warranties on all federally-funded projects.
- The Federal Government should also assist with enabling legislation to allow contract awards based upon technical and quality factors in addition to cost.
- State and local highway agencies should work to enable legislation allowing contract awards based upon technical and quality factors in addition to cost.
- Industry partners should develop an awareness and understanding of warranty issues and risks.
- State and local highway agencies should develop material and workmanship warranty programs through internal education and industry participation, and should implement short-term performance warranties when it is appropriate.

For more information about the scan or to obtain an Executive Summary of the trip's findings, contact John D'Angelo at FHWA, 202-366-0121 (fax: 202-493-2070; email: john.d'angelo@fhwa.dot.gov). A detailed report on the scan will be published this summer.

Reprinted from *Focus*, January/February 2003.

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CUSTOMER SATISFACTION

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Helping Roadway Contractors Fulfill Public Expectations

by Kathleen Bergeron

Incentive and disincentive provisions can help motivate highway builders to complete projects economically, safely, and quickly.

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A joke that made the rounds a few years back tells of a software mogul who, speaking at a computer trade show stated that if the automobile industry had kept up with technology the way that the computer industry does, everyone would be driving $25 cars that average 1,000 miles to the gallon.

The joke continues: In response, the auto industry issued a press release stating that if it had developed technology the way the software industry does, cars would have some rather odd quirks. Every time workers repainted the lines on the road, motorists would have to buy a new car. For no reason whatsoever, the car would crash twice a day. Maneuvers such as a left turn occasionally would cause the car to shut down and refuse to restart, and the motorist would have to reinstall the engine. The airbag system would ask, "Are you sure?" before deploying. And every time a new car was introduced, buyers would have to learn to drive all over again because none of the controls would operate the same as they did in the older car.

Although amusing, the story perhaps is more valuable as an object lesson than as a joke: People in the highway community might well ask themselves, "How well do I serve *my* customers compared to the way other industries serve theirs?"

How does the highway industry compare, for example, with utilities such as water, electricity, or natural gas, or with other public services? Better yet, how does it compare with more competitive consumer-products industries—manufacturers of laundry detergents, breakfast cereals, soft drinks, and, yes, automobiles and computers? On some level, all are trying to do the same thing—make their customers happy. Further, State departments of transportation (DOTs) also have the responsibility to provide a safe and efficient driving experience.

"One of the greatest challenges for State DOTs is motivating construction contractors to achieve or even surpass an agency's goals for customer satisfaction," says former New Jersey Department of Transportation Commissioner Jack Lettiere. When several contractors bid on a highway construction project, and the lowest bidder gets the job, how does the DOT motivate the winner to complete the project better, faster, or with less impact on the traveling public? In other words, how does a DOT encourage contractors to build highway projects in such a way that the process responds to the public's desires and needs?

The obvious way is simply to demand it—write specifications and contract provisions that clearly define the schedule requirements. The problem with such an approach is that the DOT may not receive any bids if it makes the project requirements too stringent, or contractors may include large contingencies in their bids to offset potential losses if they do not meet the contracting agency's schedule. Moreover, if the agency specifies exactly how it wants the project done, it is not benefiting from the creativity of the marketplace. The very basis of a free-market economy is that the company or individual who can come up with a better approach gets the advantage. So if a DOT can somehow devise a way for a contractor to use its own creativity to reach a specified level of performance, the result will be a win-win for both the DOT and the private firm.

A Two-Way Street

Of course, the challenge is not simply persuading contractors to respond appropriately to what is required of them. It also entails knowing exactly what to demand in the first place. What, precisely, does the public want with regard to particular roads or projects? And how do DOTs gather that information?

Like other government organizations, most transportation agencies maintain an office that has the responsibility of communicating with the public.

Usually the office is dubbed Public Affairs or Public Information or Public Outreach. Much of the office's work is one-way communication: telling the public the story the agency wants to deliver. The office sends press releases to the media (which, it is hoped, will convey the story to the public), distributes brochures at hearings and trade shows, and publishes newsletters geared toward specific projects that target businesses and residents who may be affected by the projects.

Although such communications help demonstrate how an agency is spending the funds entrusted to it, something may be missing. In comparison to the volume of information leaving the agency, very little feedback from highway users is brought into the organization to help determine its responses to the public's wants and needs. True communication, however, is a two-way street, providing information and listening or receiving feedback.

This deficiency is not unique to highway agencies. In a 1976 article published in *Public Relations Review*, authors Sue H. Bell and Eugene C. Bell discuss two approaches to public relations, one they call "functionary" and the other "functional." The functionary approach is based on the assumption that the purpose of public relations (or public affairs, or public outreach) is limited to effecting changes to the environment outside the organization. On the other hand, functional public relations assumes that changes can be made to the organization itself as a result of information gained from outside.

"Functionaries" attempt to preserve and promote a favorable image of the organization in the community based on the hypothesis that if the organization is "liked," the public will continue to absorb its outputs. In contrast, "functionals" seek outside information to see where the organization can better serve its constituents. So, instead of talking about "relating to the public," or "public relations," the reference is to two-way communication. And in private industry, being able to change a product or service (whether it is computers, automobiles, or whatever) to meet the public's changing needs can be critical to survival. This is important for public agencies too. Consider for a moment how local fire departments have changed over the last 50 years. Today they encompass emergency/medical response departments in addition to traditional fire suppression/prevention departments, as a result of the changing public need for these services.

In the Federal highway business, Section 128 of Title 23 of the United States Code requires public hearings whenever Federal funds are included in a highway project. But too often, comments are merely recorded. As stated in the forward to the report *Public Involvement Techniques for Transportation Decision-making* (FHWA-PD-96-031), "Acting in accord with basic democratic principles means that public involvement is more than simply following legislation and regulations. In a democratic society, people have opportunities to debate issues, frame alternative solutions, and affect final decisions in ways that respect the roles of decisionmakers. Knowledge is the basis of such participation. The public needs to know details about a plan or project to evaluate its importance or anticipated costs and benefits. Agency goals reflect community goals. Through continued interaction with the entire community, agencies build community support and, more importantly, assure that the public has the opportunity to help shape the substance of plans and projects."

Opening a Dialogue

Beyond two-way communication, where information is gained from both sides, lies the realm of true *dialogue*, where one side makes a point and the other responds constructively, and where there is, in effect, a conversation. One good example of dialogue in the highway community is now occurring on the topic of pavement performance.

In late 1995, FHWA sponsored a national survey of highway users. The survey consisted of an 18-minute telephone questionnaire with 2,205 interviews completed in the end. The responses were weighted to reflect U.S. Census Bureau norms for gender, age, race/ethnicity, education, and census region. The report that came from the interviews, the *National Highway User Survey*, looked at the public's overall satisfaction with various aspects of the highway system. "It is clear that the top priority for improving the Nation's highways is to focus on the quality of the roadway surface," FHWA and its consultants concluded. "This is the factor that will most significantly increase public satisfaction with the highway system."

Responding to that call for action, FHWA created a multiagency team in 1997 to develop and market a national pavement smoothness initiative. Using as models the pioneering incentive program for

Archived

asphalt pavement smoothness created by the Arizona Department of Transportation (ADOT) and a similar program for portland cement concrete championed by the Kansas Department of Transportation, FHWA strongly encouraged State DOTs and their contractors to focus on building smoother pavement surfaces.

The challenge was determining how to motivate construction contractors to perform above and beyond their normal levels. This is where the concept of incentives came into play. "Incentives are great tools because they enable a transportation agency to set a goal for contractors and, within certain limits, allow the contractor to use its ingenuity to come up with the means by which to achieve the goal," says FHWA Senior Pavement Design Engineer Mark Swanlund.

This approach is similar to the way the Federal Government works with automobile manufacturers to ensure regulatory compliance. Rather than specifying exactly how the car companies should build their products, the Government sets a number of general standards to which manufacturers must adhere. For example, Corporate Average Fuel Economy standards guide the fuel efficiency of a company's products in general, National Ambient Air Quality Standards govern the volume of air pollution that companies can emit, and the New Car Assessment Program sets standards for how well vehicles should handle front-end crashes.

According to Swanlund, encouraging State DOTs to adopt incentive specifications through the FHWA-sponsored pavement smoothness initiative was one of many factors that resulted in significantly improved pavement conditions on the national highway system. The "response" to the public's call for action was, in effect, the other half of a conversation between the motoring public and the Nation's transportation professionals.

Surveys Say…

But that was not the end of the conversation. In 2000 FHWA again brought the driving public into the conversation through a survey and issued a report the following year. FHWA intentionally modeled the survey on the 1995 instrument to facilitate comparison, study customer satisfaction trends, and direct future activities based on changes in the public's priorities or on improvements in public satisfaction with pavement smoothness.

The 2000 survey revealed that although pavement conditions still resonated as a significant concern (21 percent) among highway users, traffic flow (28 percent) and safety (26 percent) were now more important priorities.

In 2005 FHWA and its partners completed a third effort, the Traveler Opinion and Perception Survey. This latest effort tracks closely with earlier user surveys. The following "Important Characteristics of an Effective and High Quality Transportation System" were listed as priorities:

- Highway and roadway safety
- Ability to get where I want to go easily
- Bridge conditions
- Being able to get around as a pedestrian safely and easily
- Pavement conditions

"These results clearly show that travelers place high value on their ability to get around safely and easily," says Rebecca Elmore-Yalch, president and CEO of Northwest Research Group, Inc., the firm that conducted the survey on behalf of FHWA. "These represent the most important aspects of a high-quality and effective transportation system, and travelers wish to see this as a continued focus."

By 2005, it seemed, highway users had relegated pavement conditions to the fifth position on their list of priorities. The results do not indicate whether the highway community made a significant enough impact on pavement conditions to have an impact on user perceptions or whether user priorities simply changed over the previous decade.

A Work Zone Incentive In Arizona

Several highway agencies are using innovative incentives to encourage contractors to minimize the negative impact of highway construction on their customers. In Arizona, for example, ADOT kept an eye on customer service when it developed an incentive/disincentive approach for a $42 million project in the northwestern part of the State. The project called for widening 21.7 kilometers (13.5 miles) of State Route 68 (S.R. 68) from a two-lane rural road into a four-lane divided highway.

Rather than looking at the job as simply building a highway from point A to point B, ADOT officials took the time to understand the customers who use the route. From that, ADOT determined that this section of S.R. 68 is a major commuter route for

Archived

people who are employed by casinos and other entertainment venues across the State line in Laughlin, NV. But a large number of commercial truckers and vacationers travel the route as well. Thus, S.R. 68 does not have the morning and afternoon peak traffic periods typical of other parts of the country. Rather, a steady stream of traffic generally runs from early morning to late evening, meaning that construction crews could not simply schedule their work around the traditional rush hours.

ADOT realized early on that the construction project, which ultimately lasted almost 2 years, could have been a major headache for its customers, so agency officials set up what they termed a traffic management incentive specification. Under the specification, ADOT established an incentive/disincentive fund of $400,000 to encourage the design-build contractor to maintain a target travel time through the work zone during the entire construction schedule. To determine whether the target was met, the contractor was required to measure the amount of time it took travelers to go through the work zone. Further, the contractor had to select a method for collecting the raw data, calculating the average travel times through the work zone, and then reporting those averages to ADOT. The specification required that the average travel time not exceed 27 minutes. For each minute above that time, the contractor would be charged $21.50.

The contractor chose a measuring system that employed cameras, positioned at both ends of the work zone, to snap pictures of the license plates of vehicles entering and leaving the work zone. A central processor then matched photos of the same plates and determined the elapsed time between when the car entered and left the work zone. At the end of the project, only $14,857 had been deducted from the $400,000 incentive, thereby earning the contractor 96 percent of the bonus fund.

ADOT had hired a public relations firm for the project as well. The firm developed public service announcements, radio media alerts, a Web site, an informational phone number, and a newsletter, all aimed at keeping the public informed on the status of the project.

Critics might question whether the $400,000 incentive might have been better spent building more roadways elsewhere in the State. “Due to the lack of detour routes for S.R. 68,” responds Jennifer Livingston, then-resident engineer for ADOT’s Kingman District, “the traffic management incentive/disincentive clause was vital in minimizing delays to the traveling public, especially for commuters and those getting to and from medical appointments, government facilities, and other daily trips.”

The case becomes clearer when individual costs are considered as well. In the *2005 Urban Mobility Report,* the Texas Transportation Institute estimates that, as a national average, being stuck in a work zone costs each motorist $13.45 per hour in terms of the value of lost time. Further, each hour a commercial motor carrier sits in a congested work zone costs the firm $71.05. But in the end, ADOT received a great deal of positive feedback from the public, both for the agency’s outreach related to construction and for minimizing delays in the work zone.

A Work Zone Disincentive In New York

When congestion delays due to work zones are potentially significant, some States require contractors to suspend construction entirely during peak traffic periods. In June 2005, experts from around the country joined the New York State Thruway Authority (NYSTA) for an intensive, 2-day workshop focused on a deck replacement project on the Tappan Zee Bridge. Sponsored by FHWA’s Accelerated Construction Technology Transfer (ACTT) initiative, the workshop helped NYSTA settle on a prefabricated system that would shorten construction time and improve safety and quality.

NYSTA selected a construction method using precast concrete slabs, which offered speedy construction and minimized exposure of workers to traffic. The project involved sawing up and removing the existing pavement, putting down a bedding material, installing the slabs, grouting dowels, and then placing the bedding grout. The contractor installed about 279 square meters (3,000 square feet) of panels in each 8-hour, offpeak traffic closure.

The toll plaza services more than 125,000 vehicles per day, so any delay in opening it on time could be disastrous. NYSTA, therefore, devised a performance standard to meet the need: For every minute past 6 a.m. that the toll plaza was delayed in opening, the contractor faced a penalty of $1,300, up to a maximum penalty of $250,000 per day. The installation proved so successful that no penalties were assessed.

When Time is of the Essence

The ADOT and NYSTA projects used incentives, an approach that says to the construction contractor,

Archived

"Here's the goal you need to reach to get some bonus money. You figure out the best way of getting there." And, as in the New York case, if the contractor fails to look for innovations, it might actually lose money on the project.

Perhaps the most widely used performance specification is one focused on how quickly a contractor can complete a project. More and more, agencies are recognizing that the bottom line construction cost of a project has to include the impact on the driving public. So the DOTs offer contractors monetary incentives for early completion with the daily incentive amount based on estimated road-user costs.

A case in point: On January 5, 2002, a gasoline tanker traveling Interstate 65 (I-65) within the I-20/I-59/I-65 interchange in Birmingham, AL, crashed and burned under a bridge. The fire caused the steel girders of the main span over southbound I-65 to sag about 3 meters (10 feet), which required closing all northbound and southbound lanes. Removal of the damaged bridge began as soon as the wreck was cleared, and northbound traffic was restored the next day. The Alabama Department of Transportation (ALDOT) estimated costs to road users caused by the southbound closure at $90,000 per day.

ALDOT designed a new concrete girder bridge and awarded the contract on January 16. Construction began January 21. The contract allowed 90 days for completion of the new bridge, with an incentive/disincentive provision of $25,000 per day. The successful bidder completed the new bridge in 37 days, earning an extra $1,325,000. The contract cost, including the incentive payment, was still less than the cost proposed by the second-place bidder.

"Within 53 days, the damaged bridge was removed, the design completed, and a new bridge built, demonstrating intense commitment and cooperation among all parties involved," says FHWA Alabama Division Administrator Joe Wilkerson, "especially State engineers, the concrete fabricator, and the contractor that built the new bridge."

New Mexico Uses Innovative Incentives

A look at a New Mexico example ties many elements of the story together. A recent project needed speedy construction, and the New Mexico Department of Transportation (NMDOT) added its own twist. Reconstruction of the I-25 and I-40 interchange in Albuquerque required construction or rehabilitation of 55 bridges and 177 kilometers (110 miles) of roadway. Lacking viable alternate routes, NMDOT had to complete the project while motorists continued to use the roadway.

The original interchange was designed in 1967 to support 40,000 vehicles per day. At the time of its reconstruction, however, it was severely overutilized, with an estimated 300,000 vehicles daily. Congestion resulted in an average 1.7 crashes per day, with an economic impact estimated at $12 million annually.

In the end, reconstruction enhanced the level of service and reduced the crash rate on the most heavily traveled interchange in the State. NMDOT estimates that the new interchange will benefit the Albuquerque economy by approximately $1 billion over the first 10 years. The public benefits from reduced travel time, enhanced safety, and environmental improvements.

To minimize disruption to the community, NMDOT decided to reconstruct the interchange under a single contract with incentives to keep construction time under 2 years. But with little funding available for monetary incentives, the agency offered the contractor innovative incentives, most notably ownership of excess right-of-way if the project was finished ahead of schedule. NMDOT purchased an 8.5-hectare (21-acre) parcel that included about 1.6 hectares (4 acres) of required right-of-way, with the remainder used as a staging area during construction. Since construction was substantially complete before the contract calendar date, the contractor received the deed to the remaining 6.9-hectare (17-acre) parcel. Ultimately, several tracts of land owned by NMDOT and deemed in excess of future highway needs were transferred to the contractor in lieu of cash incentives.

To minimize the impact on traffic, the project team used progressive techniques, such as segmental bridge construction, and established a traffic surveillance system and incident response program for the construction area. Through close contact with the media during the project, NMDOT cultivated public support by apprising motorists of potential delays. In the end, the incentives and careful management paid off: The completed interchange opened to traffic in May 2002, after only 23 months of construction.

Staying Tuned

The need to learn what the public wants has been recognized for decades. As noted in the FHWA report *Moving America: New Directions, New Oppor-*

Archived

tunities, published in February 1990, "An understanding of what Americans want from their transportation system is as important to the formation of transportation policy as analysis of facts and figures."

But understanding what the public wants and needs—whether smoother roads, less interference with traffic by construction, or something else—is not necessarily the same as attaining the desired level of performance from U.S. highways. Incentives and disincentives are an invaluable tool for attaining those levels of response.

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Reprinted from *Public Roads*, March/April 2006.

Archived

Selected Customer-Focused Activities at FHWA

Knowing what needs to be done and having the tools to do it are two separate things. So how does one move to a more customer-focused approach, both in personal approaches and organizationally? FHWA sponsors a number of programs and activities that can help State and local agencies improve their delivery of quality roadway projects. They include the following:

National Highway Institute Course. Public Involvement in the Transportation Decision-Making Process (#142036) is a 3-day course that teaches attendees how to identify key decision points where the public should be involved. Among the topics covered are selecting and applying specific techniques for sharing information with the public, identifying and adapting to different cultural sensitivities, and developing public involvement plans. For more information, visit www.nhi.fhwa.dot.gov.

Accelerated Construction Technology Transfer (ACTT). ACTT is a program through which State DOTs can gain access to a team of nationally recognized leaders in an array of disciplines who conduct a workshop focused on a single highway corridor or project selected by the host agency. For more information, visit www.fhwa.dot.gov/construction/accelerated.

Performance Specifications Strategic Roadmap. FHWA developed this report as a tool to guide the highway community in developing, implementing, and accepting performance specifications as viable tools for highway construction. To view the roadmap document, visit www.fhwa.dot.gov/construction/pssr04tc.htm.

Transportation Curriculum Coordination Council (TCCC). The TCCC is a partnership between FHWA, State DOTs, and the highway transportation industry to support the training of the highway construction personnel. The council provides a core curriculum of materials and training available to State and local transportation agencies. For more information, visit www.nhi.fhwa.dot.gov/tccc.

Sometimes Quality Is in the Eye of the Beholder

by Kathleen Bergeron

Highway users and other stakeholders share their views on what makes a successful road project.

Archived

A familiar parable from India tells of six blind men who came upon an elephant for the first time. As each man touched a different part of the animal, he came to a different conclusion about the elephant. The first felt the pachyderm's side and said that an elephant is like a wall. Others, upon touching the elephant's tusk, trunk, knee, ear, and tail, argued, respectively, that the elephant certainly was more like a spear, a snake, a tree, a fan, or a rope. As John Godfrey Saxe concluded in a poem based on the fable (paraphrased), "though each was partly in the right, all were in the wrong." A one-dimensional viewpoint rarely tells the full story.

Consider a modern example of this principle. During the planning of a roadway in Cupertino, CA, several years ago, local authorities proposed building a major highway interchange. Although the design seemed to fill the need, according to San Jose's *The Mercury News*, local residents derided the plan as a "Berlin Wall," because its height would physically split the community. Residents wanted the interchange sunk below ground level to reduce the visual impact and traffic noise. The engineer from the traffic authority, however, refused to compromise, arguing that during storms the nearby creek might flood a below-grade interchange. The residents returned a few days later with a petition signed by 1,800 residents, demanding the below-grade approach. Finally bending to the show of political force, the traffic authority went forward with the sunken design.

But that was not the end of the story. When *The Mercury News* article ran in February 1998, it was part of a larger piece on the extensive flooding from that year's El Niño phenomenon. The writer pointed out that during the week before the article ran, the interchange flooded for the second time in 3 years. The reporter asked a local resident how the community felt about the sunken interchange now, since the engineer had been proven correct about the flooding. The resident responded, "Our view was that if it only happens once every 100 years, we can live with it. It's better than having the large concrete structure."

It is not unusual to find that what engineers and planners see as the perfect solution to a transportation problem may not conform to the residents' ideas of perfection. As with the blind men in the parable, determining the true nature of the beast requires a number of viewpoints. This principle is at the heart of why public transportation agencies hold listening sessions during the planning stage of a project. Even though transportation agencies are staffed with experienced and knowledgeable design and construction professionals, they often are focused on just a few aspects of the overall project. Failing to address the concerns of other stakeholders —including the driving public, disabled persons, trucking and bus operators, and business owners along the right-of-way—leads to a narrow viewpoint and approach that may cause problems in the future.

The USDOT Approach

When officials at the U.S. Department of Transportation (USDOT) and the Federal Highway Administration (FHWA) decided to look more closely at their approach to designing highways, they sought to capture the perspectives of multiple stakeholders. Asking only the people who design or build the highways is not enough.

"Our focus on the customer must drive our priority setting and the way we use our resources, right down to how each of us spends our day," says FHWA Executive Director Frederick G. "Bud" Wright. "Our choices must be governed by what we know to be the most important needs of our customers, because we have asked them."

In 2003, USDOT sponsored a series of listening sessions with representatives from several key

groups, including owners and operators of highways, contractors who build roads, suppliers of construction materials and equipment, and users of the highway system. The purpose was to shed light on how the various constituencies view and define the notion of quality in highways and construction projects.

Each session lasted several hours and began with a brief orientation on a topic related to improving the quality of the Nation's highways. The participants met with key highway leadership at USDOT, including Transportation Secretary Norman Y. Mineta, FHWA Administrator Mary E. Peters, and Federal Motor Carrier Safety Administration (FMCSA) Administrator Annette M. Sandberg. The hosts posed specific questions and then opened the floor for discussion.

The diversity of opinions expressed by the participants suggested that definitions of *quality* depend on the perspective of each respondent. Followup interviews with a few of the participants highlight some of the key factors identified as important to specific constituencies and emphasize the value of inviting diverse stakeholders to the table when planning highway projects.

The following questions and responses were posed to Darrin Roth, director of highway operations at the American Trucking Associations (ATA); Mike Acott, president of the National Asphalt Pavement Association (NAPA); Val Riva, president of the American Concrete Pavement Association (ACPA); Kathleen Marvaso, managing director for government relations and traffic safety policy at the American Automobile Association (AAA); and John Bukowski, a pavements engineer at FHWA.

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What Is a *Quality* Highway?

The *Merriam-Webster Online Dictionary* defines *quality* as "degree of excellence." This article discusses what quality means to a customer in defining a finished product, not as criteria or management concepts from the Baldrige National Quality Program. To transportation officials, the degree of excellence typically relates to pavement smoothness and durability, adherence to budget and schedules, and improved road safety. Input from some of the participants in the listening sessions and followup interviews help broaden this definition.

Darrin Roth (ATA): "The term 'quality' in general is very important for the trucking industry because individual companies have to be able to distinguish themselves from their intramodal and railroad competitors. As far as the customer is concerned, price is always a consideration. But that's usually secondary to meeting certain standards of quality, or customer expectations. For the trucking industry's customers, quality means that the shipment is picked up or delivered on time and without damage, and that the customer is notified of any unexpected occurrences when they happen so necessary adjustments can be made. Similarly, highways should be built and maintained in a way that meets customer expectations of smoothness and reliability, and price may be a secondary concern."

Mike Acott (NAPA): "When we look at quality, we look at it from the perspective of both the user and the engineer. From the highway user's perspective, we're concerned with how well the pavement rides, how smooth it is, the noise level, skid resistance, and speed of construction. From the engineering side, we look at the materials and mix design, the consistency of the material, and the density specifications, so that it will provide good performance."

Val Riva (ACPA): "In the concrete pavement industry, quality is synonymous with exceptionally good long-term performance and minimal maintenance and rehabilitation requirements. Quality pavements combine all aspects of design and construction, including project management, materials, equipment innovations, process control, workmanship, and the like. It's not one thing that makes a quality pavement—it's attention to *everything*."

John Bukowski (FHWA): "Let me give a narrow definition for those of us who might be called 'stewards' of the highways—and by that I mean those whose job it is to see that highways are designed, built, and maintained for the public good—organizations like FHWA and State and local transportation agencies. For us, a narrow definition would tie in with what we call 'quality assurance.' That means we look at certain parameters such as how good the materials are and how smooth the final surface is. These can be measured. So 'quality' in that narrow sense means falling within those prescribed tolerances. In a broader sense, quality to us means the final product also has to meet the expectations of the users, in terms of longevity, noise, and smoothness."

Kathleen Marvaso (AAA): "As the largest organization representing motorists—the primary user group—we define quality in terms of safety and mobility. We recognize the critical importance of properly designed and maintained roads to serve existing and future mobility needs, and the safety benefits gleaned by improved road design and construction. The transportation network is essential to commerce and the Nation's ability to prosper in a global economy, to improve our quality of life, and to facilitate national and civil defense. The ongoing need for safe, well-maintained roads and bridges is critical for the millions of Americans who travel for business or leisure."

What Is Most Important When Building a Quality Highway?

To build and maintain successful highways, Federal, State, and local transportation agencies need to make *quality* a primary focus during the life of a project—planning, design, construction, and maintenance. Typical factors that influence the direction and scope of highway projects include an evaluation of the need for the new facility, anticipated future traffic demand, improved safety, specifications for performance and durability, and environmental, cost, and scheduling considerations. The interviews with key stakeholders elicited further opinions on what constitute the most important aspects of highway quality.

Darrin Roth (ATA): "Time between maintenance and repair cycles, and geometric design that accommodates the configuration of vehicles expected to use the highway."

Mike Acott (NAPA): "One of our goals is to design and build pavements that are long lasting. We talk about 'perpetual pavements,' meaning that you design the roadway so that the only work that needs to be done is on the surface. It's like a builder who builds a house. Periodically, the roofing material needs to be replaced, and some other minor maintenance, but if he builds it well, it can last a long, long time."

Val Riva (ACPA): "Our thought is that it's important to address all aspects of design and construction. Our industry is working continuously to improve the products and processes used in paving, while also working closely with agencies to address design and construction considerations.

"We cannot overlook the need for applied research, which is essential to developing safer, more cost-effective, and better performing highways. It's imperative that this research effort involve all stakeholders to ensure we are meeting the needs of agencies and the traveling public, based on input from road builders, researchers, and public officials."

John Bukowski (FHWA): "One of the things that we talk about is speed of construction, and there are a number of tools to accomplish this—fast-setting concrete or asphalt, innovative project management techniques, or even innovative design approaches."

Kathleen Marvaso (AAA): "Safety must be paramount in all stages of road design—from planning to construction to signage. Our members tell us that they want a transportation system that is reliable, efficient, and safe. They want road repair and maintenance work to be completed on schedule, and they want their gas tax dollars at work improving the transportation systems they use in their daily lives. Educating the public to engender trust that their taxes are spent wisely is critical."

What Should Be Considered During Planning?

During the planning stage, State departments of transportation (DOTs) increasingly are designing roads that fit into their physical settings and preserve scenic, historic, cultural, and environmental resources, while improving safety and mobility. Known as context-sensitive design, this approach involves reaching out to stakeholders within and outside the highway community to identify transportation solutions that will add lasting value to the community. The interviewees zeroed in on specific attributes of the planning process that their constituencies see as integral to building a quality highway.

Darrin Roth (ATA): "Longevity of the highway is important, particularly in urban areas, since congestion has become a major problem. Therefore, using longer-life pavements in certain areas, including urban settings and regions subject to freeze-thaw cycles and other harsh environmental conditions, is critical to avoiding frequent road construction. In addition, trucks have operating characteristics that

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require geometries that are different from those required for cars. This includes wider shoulders. Trucks are 102 inches wide [2.6 meters], so even a 10-foot [3-meter] shoulder only leaves 18 inches [46 centimeters] of clearance when the truck is pulled onto the shoulder.

"Trucks take longer to accelerate, so longer on-ramps are necessary and should be gradual. Many trucks will take a ramp too fast, causing the load to shift and possibly tip the vehicle over. One effective remedy is to install a message board on the ramp warning trucks to slow down. Since many truckers serve customers in unfamiliar areas, good signage is important. Signs usually are designed to accommodate the line-of-sight for passenger vehicles, but since truckers sit higher up, they may miss the signs. It may be worth looking into having top and bottom signs on the same pole in certain areas where traffic is moving at high speeds. Also remember that because trucks are much higher than passenger vehicles, they may block the view of signs and overhead traffic signals for motorists idling behind or next to a truck."

Val Riva (ACPA): "It's important to plan for every contingency that can occur on the grade. We've seen examples of excellent projects, which from the earliest stages involve a comprehensive outreach effort to ensure communication among those involved in and affected by the project. This [outreach] not only includes specifying agencies and the industry, but also the public, law enforcement agencies, business leaders, and others."

John Bukowski (FHWA): "One critical thing is how much you're going to disrupt the local traffic. In terms of materials, perhaps you want to use a quick-setting pavement. Or in terms of scheduling, maybe you want to have the work done at night or on weekends.

"Another aspect is communication with the work crews. Some of the best projects we have are ones using new technology. I think maybe some of that is because when we use a new technology, we spend an inordinate amount of time bringing the crews in early to show them how to use the technology. The challenge comes when it gets to the point of becoming a standard procedure. There's a tendency not to communicate as much because everyone is assumed to know what their job's going to be."

Kathleen Marvaso (AAA): "Communication with the public is key. Advance notification announcing road closings or construction delays allows motorists to make decisions regarding their drive time. Providing motorists with options to take a different route or travel at less congested times can help alleviate some of the frustration drivers experience when driving through highway construction areas.

"Increased visibility of law enforcement and patrol cars are two ways to improve work zone safety. As part of our commitment to traffic safety, AAA includes tips for safer driving in work zones in our manuals and driver improvement classes. The AAA Foundation for Traffic Safety, a nonprofit research and educational organization, has created a variety of materials, including a video highlighting safe driving practices in work zone areas."

During Construction, What Is Most Important to Your Constituents?

Achieving national objectives for mobility depends on constructing highway improvements to a desired level of quality to ensure long-lasting performance and reduce impacts on traffic, congestion, and the environment. Safety is improved by minimizing the frequency, duration, and extent of work zones, which disrupt the normal flow of traffic. In addition to these considerations, the interviewees noted specific techniques or approaches that agencies can use to enhance the operation of work zones.

Darrin Roth (ATA): "Work zone lanes should not be so narrow that trucks have a difficult time getting through. Also, providing information about lane closures and other restrictions through a phone hotline or Web site would help truckers immensely."

Val Riva (ACPA): "In addition to building fundamentally high-quality pavements, we're also focused on maximizing safety and minimizing disruptions to road users. It's imperative that we do all we can to ensure the safety of the traveling public and work zone personnel."

John Bukowski (FHWA): "For the people who actually oversee the projects, it's a matter of making sure that the work is coordinated in one continuous flow, one smooth operation—what you might call the logistics of the project. You have to make sure the contractors have the proper materials available and

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the work zones are marked off properly. Once one of these operations gets going, it becomes critical that all the right pieces are in place. You can't, for example, have a truck driver not show up and the whole process shuts down."

After the Highway Is Completed, What Spells Success?

Resources like the "National Highway Specifications" Web site at www.specs.fhwa.dot.gov, which consists of a searchable library of highway specifications from across the country, provide the framework with which engineers evaluate construction projects, from the quality of materials to the final pavement smoothness. FHWA and State DOTs also consider cost-effective completion, enhanced safety during and after construction, long-life durability, visual appearance, noise reduction, and improved mobility as primary measures of a project's success. How do other stakeholders rank successful highways?

Darrin Roth (ATA): "Quality management and information dissemination. Clear crashes quickly, clear snow and ice, etc. If there's a crash, make that information widely available quickly so truckers can plan alternate routes."

Val Riva (ACPA): "One of the key measures of success is the assurance that the pavement will live up to design expectations and fulfill an important promise to taxpayers and other stakeholders: Get in, do it right, get out, and stay out. We are focused on providing the best long-term, cost-effective investment to agencies and the traveling public."

John Bukowski (FHWA): "The key question is, 'What kind of quality did you build into it?' Quality doesn't mean simply that a pavement project receives high marks upon completion. It's important to anticipate the level of use it will get. Quality is not about providing a usable road today. Not if 3 or 5 years from now the pavement starts breaking down. Then it wasn't a quality project. Part of our problem is that we design a highway to last 20 years, and then the level of wear and tear on that section of highway is way out of proportion to those early estimates. We need to do a better job of anticipating the patterns and magnitude of growth that we anticipate our highways will have to endure."

In Terms of Maintenance, What Is Ideal?

As demands on the Nation's highway system continue to grow, finishing maintenance jobs quickly and effectively has never been more important. Extended construction and maintenance activities increase travel time and costs for highway users, affect the flow of commerce, and prolong safety risks to motorists and highway workers. But through strategies like conducting work during nights and weekends and using preservation techniques that help extend the life of existing pavements, DOTs are improving the speed and reducing the duration of maintenance activities.

Darrin Roth (ATA): "Deferred maintenance is more costly and disruptive to traffic than regular maintenance, so establish the right schedule and stay with it. Get in and get out as soon as possible. While weekend and nighttime road work is more expensive, it pales in comparison to the costs involved with crashes and congestion caused by road work during times of heavy traffic volume."

Mike Acott (NAPA): "The goal should be that any work on the pavement is limited to periodic resurfacing. If complete rebuilding of the pavement is required, then you've failed to meet the needs of the road user."

Val Riva (ACPA): "Noting that a quality concrete pavement is one that requires little or no unscheduled maintenance, the ideal is to follow a well-planned preventive maintenance program. Routine maintenance for concrete pavements essentially requires periodic joint resealing. Although required on an infrequent basis, it is nonetheless an important part of assuring good long-term performance."

How Important Is Smoothness?

Pavement smoothness, sometimes called road condition or roughness, is one attribute that is important for the ride and operation of roads. Almost a decade ago when FHWA performed research on this aspect of roadways, it found that smoother roads do have a definite impact over time—for the owner or agency and for the user. A survey by the National Quality Initiative (now the National Partnership for Highway Quality) indicated that pavement smoothness is one of the most significant measures motorists use to judge the quality of the Nation's

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roads. Pavement smoothness directly relates to driver comfort as well as the life expectancy of pavements. The interviewees echoed this concern for smoothness.

Darrin Roth (ATA): "Average operating costs for a truck on a poor road surface versus a good surface is 12 cents per mile [7 cents per kilometer]. In addition, poor surfaces can damage cargo and contribute to crashes."

Val Riva (ACPA): "Good long-term performance is affected by pavement smoothness, which should not be confused with texture. Smooth pavements do not experience the dynamic loads of rough pavements, which means less wear-and-tear on vehicles and the pavement. There are tangible benefits in terms of reduced costs to road users and agencies, and, of course, the taxpaying public."

How Important Is Overall Traffic Flow?

Strategies to improve or maintain efficient traffic flow range from expanding roadway capacity to enhancing the operation of existing facilities. DOTs are deploying a growing variety of intelligent transportation system (ITS) technologies that monitor and manage flow, such as electronic toll payment systems, video surveillance, weather information services, and weigh-in-motion technologies. These approaches can help keep traffic moving and reduce the impact of factors like construction, weather, and crashes that inhibit mobility. Interviewees stressed the importance of improving traffic flow to the economy and personal travel.

Darrin Roth (ATA): "Just-in-time [JIT] delivery saves the U.S. economy around $700 billion per year through lower transportation costs and reduced inventories. JIT has enabled retailers, wholesalers, and manufacturers to reduce their inventories substantially, reducing freight transportation and logistics costs from 16 percent of the gross domestic product in 1980 to 10 percent today. JIT is only possible with reliable deliveries, and predictable traffic flow is critical to reliable deliveries."

Val Riva (ACPA): "We have developed some innovative solutions to improve work zone safety and minimize traffic disruptions, such as a comprehensive guide and ongoing training in traffic management during construction, as well as fast-track methods of construction."

Kathleen Marvaso (AAA): "AAA members would measure success by the improved mobility and safety they see as road improvements are made. What does that mean? Fewer crashes and reliable travel times. Well-designed and maintained roads reduce the frequency of crashes. Are the driving lanes and shoulder areas wider? Are roadside hazards a safe distance from the travel lanes? Infrastructure improvements should be aimed at accommodating, rather than stifling, projected growth in travel demand."

How Important Is Traffic Flow in Work Zones?

Work zones account for nearly 24 percent of nonrecurring congestion, or 482 million vehicle-hours of delay per year. ITS technologies are a key tool in maintaining traffic flow in work zones. Dynamic lane-merge systems, for example, facilitate efficient and safe traffic merging as vehicles approach closed lanes in a work zone. And real-time data gathered through ITS technologies can be synthesized and reported to motorists through variable message signs, Web sites, and traveler advisory radio. Constituents consistently reported that communication is essential to improving mobility in work zones.

Darrin Roth (ATA): "Truckers will try to avoid work zones if possible, but they need to be aware that they exist."

Mike Acott (NAPA): "Less time in the work zone is key. The idea is to build the pavement so that all you ever need to do is periodic overlays, nothing more. If you can get to that mode, then delay time will be minimal."

Val Riva (ACPA): "By its nature, a quality pavement will help reduce congestion and costs by minimizing the downtime associated with construction, maintenance, and rehabilitation."

Kathleen Marvaso (AAA): "Traffic flow is extremely important to our members, and work zones are a source of frustration. Time is a precious commodity in our society. Whether it's movement of people or freight, the Nation depends on its transportation infrastructure. Keeping traffic flowing safely through work zones is critical."

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How Important Are Safer Highways?

More than 41,000 fatalities occur on U.S. roadways each year. In 2003, Transportation Secretary Mineta challenged USDOT and the States to reduce the Nation's highway death toll by decreasing the fatality rate, currently at 1.5 fatalities per 100 million vehicle miles traveled, to 1.0 by 2008. Once again, the interviewees made some telling points regarding their constituents' concerns with highway safety.

Val Riva (ACPA): "Safety is one of the most compelling arguments for investing in highways and roadways. As a Nation, we should be outraged by the number of fatalities attributable to road conditions, as well as those occurring in work zones. In designing and constructing safer highways, it is imperative that we examine all aspects of the highway, including some basic pavement construction variables such as geometry and surface texture."

Kathleen Marvaso (AAA): "According to a 1995 report by the AAA Foundation for Traffic Safety, *Safety Effects Resulting from Approval of the National Highway System*, increasing the lane width to 12 feet [3.7 meters] from 10 feet [3 meters] or less could lead to a 12–40 percent decrease in crashes. Decreasing road curvature by 20 degrees could lead to a decrease of nearly 50–75 percent."

Darrin Roth (ATA): "Safety is the trucking industry's number one priority."

How Important Is Reduced Air and Noise Pollution?

Highway traffic noise—emanating from vehicle engines, exhaust systems, and tires interacting with pavement—affects the quality of life for nearby residents and businesses by drowning out conversations, disrupting sleep, and discouraging outdoor activities. Given that clean air and minimal traffic noise are qualities sought by all road users, how important is reducing air and noise pollution?

Darrin Roth (ATA): "Important from a 'good citizen' standpoint, but also because pollution concerns —particularly noise—are a factor in many access restrictions for trucks. Obviously, congestion is a major cause of air pollution for all vehicles."

Kathleen Marvaso (AAA): "Transportation and environmental stewardship should be complementary goals. Integrating all modes of transportation into a system that maximizes the utility of each for the benefit of the traveling public should be our goal. Employing as many tools as possible to improve the system and protect the environment reaps rewards for all transportation users."

How Important Is Compatibility with the Environment?

The public expects Federal, State, and local governments to provide highway, transit, and bicycle and pedestrian improvements that are environmentally sound, that are safe, and that maintain a standard of mobility that is envied by the world. In fact, in 2001, FHWA identified environmental stewardship and streamlining as one of the agency's "vital few" priorities, along with safety and congestion mitigation.

John Bukowski (FHWA): "The group I called the 'stewards' constantly have to balance factors against one another. We cannot always get 100 percent in every area. For example, if we want to be environmentally sensitive, we might consider using 100 percent recycled materials on a highway construction project. But if we do that, the overall physical quality of the pavement will suffer. So we have to determine how much recycled material we can use, while maintaining an acceptable quality level. Now, multiply that by all those other areas—safety, noise, and cost reduction, just to name three—and pretty soon you see how multilevel the tradeoffs become."

How Important Is Spending Less Money?

Weighing the multiple factors, benefits, and costs of highway projects is important before moving forward with any action. Factors include safety, community involvement, materials, longevity, projections, maintenance, and a score of other variables. In this time of tight budgets and competing demands for available resources, how can highway owners deploy limited resources to achieve all of these goals?

Darrin Roth (ATA): "I would suggest spending money more effectively. A greater upfront investment in capacity, longer-lasting pavements, and better designed highways will prevent costly improvements later on. These costs are for both capital improvements and the larger economic costs associated with poor ride quality, more crashes, and

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greater congestion. Furthermore, States should reevaluate decisions to build or expand lesser traveled roads at the expense of interstates and other major arteries."

Val Riva (ACPA): "We are very focused on spending less money, but no discussion about investment in our highways would be complete without factoring in safety. One need only think of the costs associated with work zones, vehicle damage, and disruptions to imagine the magnitude of the savings."

Kathleen Marvaso (AAA): "Transportation investments require long-term, reliable, and sustainable funding. Demands on the system continue to grow, and despite significant increases made possible by TEA-21 [the Transportation Equity Act for the 21st Century], documented needs still outstrip available funding. Funding decisions made today will directly influence the safety and efficiency of tomorrow's transportation system."

How Do Your Organization's Members Measure Road Quality?

So then, when all is said and done, what is needed in order to earn that label "quality" on a highway?

Darrin Roth (ATA): "Our main concern is with reliability, which can be affected by crashes and response time and levels of congestion. Almost as important is travel speed. A highway in good condition will be largely free of ruts and potholes. The highway's bridges and its geometric design should be able to handle the types of vehicles that use the road."

Val Riva (ACPA): "The defining measure of quality in highway or road construction is whether we met the long-term performance expectations with minimal maintenance and rehabilitation requirements. Our goal is to construct pavements to the standards set forth by the specifying agency . . . or better. We measure material quality, as-constructed variability, thickness, smoothness, and other criteria to assure that expectations have been met. Meeting these expectations means that we've placed a pavement that returns the best value to our ultimate customers . . . the traveling public."

From Parable to Drivable

Like beauty, quality is in the eye of the beholder. The more involvement in defining, evaluating, and verifying the quality of a highway project, the more likely it is to be something universally recognized not as a wall, snake, spear, or even an elephant, but as a highway that serves the needs of all road users.

At the close of one of the listening sessions, FHWA Administrator Mary E. Peters remembered a discussion she once had with a project manager for a major construction contractor in Phoenix who was concerned with being able to deliver pavement materials to a job site in a timely manner. His choice for someone to talk to and compare notes with was an employee at a national pizza delivery chain. If the drivers could deliver pizzas within 30 minutes, he should be able to learn something from the restaurant chain about how to schedule drivers and plan routes. "Like that contractor," said Peters, "we've got to recognize that sometimes our best input comes from someone with a totally different perspective than ours."

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Reprinted from *Public Roads,* May/June 2004.

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NATIONAL PARTNERSHIP FOR HIGHWAY QUALITY

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Conference Captures the Many Faces of Highway Quality

Unique construction methods, mega projects that are changing the face of transportation for their communities, and progressive new partnerships were three of the many faces of highway quality on display at the National Partnership for Highway Quality's (NPHQ) 2005 Quality Conference. NPHQ brings together State, Federal, and highway industry leaders to encourage the use of quality practices that will improve safety and service for highway users. Held December 13-14, 2005, in Orlando, Florida, the conference spotlighted groundbreaking practices across the country. "The conference provided an excellent opportunity to learn from some notable, quality-managed programs," said Bob Templeton, Executive Director of NPHQ. Conference attendees included State department of transportation (DOT) officials and design, construction, and project engineers; officials, managers, and engineers from private industry; and Federal Highway Administration (FHWA) representatives.

"Quality as a mechanism allows us to deliver a motivating work environment for our employees, while at the same time delivering what our customers want," noted conference keynote speaker Pete Rahn, Director of the Missouri Department of Transportation. Among the quality projects highlighted at the conference was the Iowa DOT's construction of the new U.S. 20 Iowa River Bridge in Hardin County. Using an innovative construction method known as incremental launching, the superstructure of the new bridge was assembled on one side of the river and then rolled some 496 m (1,630 ft) across the river valley into its final position. The incremental launched-girder technique eliminated the need for the temporary erection towers and in place erection of structural steel required by conventional construction methods. This allowed Iowa DOT to meet the stringent environmental requirements of constructing the bridge in the Iowa River Greenbelt, a rare, remaining piece of old-growth woodland. The project's innovation was honored with NPHQ's 2005 National Achievement Award.

The Colorado Department of Transportation's Transportation Expansion Project, or T-REX, also provided a vivid example of quality practices. The $1.67 billion multimodal project is improving 27 km (17 mi) of highway in the metropolitan Denver area, along with adding 30 km (19 mi) of light rail service. Its $1.2 billion design-build contract is the largest in the country and the first to encompass both highway and transit elements. Groundbreaking for the project began in September 2001, with completion scheduled for the end of 2006. Accelerated construction has been a hallmark of the project. "T-REX is sprinting into its final year 22 months ahead of the original estimated completion, thanks, in part, to performance specifications that give the contractor the latitude to innovate and improve,"

The Iowa River Bridge in Hardin County, IA, was assembled on one side of the river and rolled 496 m (1,630 ft) across the river valley into position.

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The T-REX project in Denver, CO, includes the reconstruction of 11 bridges spanning I-25. The Colorado Boulevard Bridge over I-25 was one of three bridges rebuilt in phases, so that traffic could be maintained on the structure at all times.

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said Dave Geiger, Director of the Office of Asset Management at FHWA.

NPHQ's new accreditation process for state quality partnerships (SQPs) was also a featured topic at the conference. SQPs comprised of transportation stakeholders who meet regularly and share common goals for the continuous improvement of highways and bridges can provide numerous benefits to States, including improved partnering on projects, cost savings, greater efficiency, and increased customer satisfaction. SQP members typically include representatives from the State DOT, FHWA division office, industry associations, city and county offices, and other stakeholders. "An SQP advances service, safety, efficiency, and environmental stewardship," said Templeton. "It sends a clear message that a State DOT plans to capture every opportunity to serve the driving public and boost economic prosperity. While the SQP concept is still new to many people, I think we're gaining some momentum." NPHQ's goal is to have an SQP in every State by 2008.

Greg Mayo and Georgene Geary of the Georgia Department of Transportation (GDOT) told conference attendees how Georgia transformed its 12-year-old Georgia Quality Initiative into the new intermodal Georgia Partnership for Transportation Quality (GPTQ), becoming the first SQP to receive NPHQ accreditation. GPTQ includes original members of the Georgia Quality Initiative, such as GDOT, the Georgia Highway Contractors Association, and FHWA's Georgia division office, as well as new partners ranging from the Georgia Transit Association to the Georgia Transportation Institute. GPTQ's initiatives include workforce training for highway personnel. To learn more about GPTQ, visit www.gptq.com. Guidelines for starting an SQP and applying for NPHQ accreditation are available in NPHQ's booklet, *How to Grow an SQP.* The booklet can be found online at www.nphq.org (click on "State Quality Partnership Resources").

For more information about NPHQ or the 2005 Quality Conference, or to subscribe to NPHQ's newsletter, contact Bob Templeton at NPHQ, 512-301-9899 (fax: 512-301-9897; email: btemplenphq@aol.com), or visit www.nphq.org.

Reprinted from *Focus,* April 2006.

Iowa Launching

by Bob Templeton

Joining environmental sensitivity with innovation, the Iowa Department of Transportation (IDOT) met the many challenges of constructing the new U.S. 20 Iowa River Bridge in Hardin County by using a unique construction method known as incremental launching. This innovation has been honored with the National Partnership for Highway Quality's (NPHQ) 2005 National Achievement Award. NPHQ brings together state, federal and highway industry leaders to encourage the use of quality practices that will improve safety and service for highway users.

The new bridge is located on U.S. 20 in the Iowa River Greenbelt, a rare remaining piece of old-growth woodland. The site is home to roosting bald eagles and endangered species of freshwater mussels, as well as historical Native American artifacts. While building the bridge was integral to the state's effort to expand U.S. 20 to four lanes, the challenges were considerable. Construction equipment was prohibited from crossing or entering the river, and all construction activity had to be completed within a small footprint surrounding the bridge. With these stringent restrictions, IDOT and its project partners, HNTB Corp. and Jensen Construction, quickly ruled out using conventional erection methods for the 1,630-ft bridge. Employing the incremental launched-girder technique instead eliminated the need for the temporary erection towers and piece-by-piece in-place erection of structural steel required by conventional methods.

Using the launched-girder method, the superstructure of the bridge was erected on one side of the waterway and then rolled across the river into its final position. The technique has been used for years in Europe to erect concrete-box structures and also had been used for a smaller steel-box girder railroad bridge in the U.S. However, it had never been used to launch a long-span I-girder bridge made up of nearly 10 million lb of structural steel.

Construction of the bridge began in August 2000. The bridge's 10 302-ft spans were launched after completion of steel erection in a specially excavated 15-ft-deep, 600-ft-long launching pit behind the bridge's east abutment. A temporary launching nose was attached to the front of the first span, and large hydraulic rams pushed the structural steel into place on a system of guided roller bearings. This sequence was repeated for the other spans. The entire steel bridge system, including all diaphragms, lateral bracing and drain pipes, was successfully launched at a pace of approximately 1 ft per minute.

The bridge opened to traffic in August 2003, shaving 15 miles and more than 30 minutes off the commute between I-35 and Waterloo, Iowa, while still preserving the natural resources of the area. Its slender, low-profile structure was designed to blend in with the area's natural surroundings. The use of weathering steel, meanwhile, will reduce the need for future painting and maintenance.

The innovative project's success has led to launched steel girder bridge projects in other states, such as a bridge constructed near Moorefield, W.Va. The Federal Highway Administration's Accelerated Construction Technology Transfer program also has identified incremental launching as an option for quick and safe bridge construction.

Bob Templeton is the executive director of the National Partnership for Highway Quality.

Reprinted from *Road & Bridges*, February 2006.

Archived

A Commitment to Quality

by Dennis Merida

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For the New Jersey Department of Transportation (NJDOT), replacing a deteriorated drawbridge built in 1922 resulted not only in a gleaming new structure, but in a project distinguished by innovative design features and a commitment to quality. This commitment was honored with the National Partnership for Highway Quality's (NPHQ) 2003 National Achievement Award. NPHQ brings together state, federal and highway industry leaders to encourage the use of quality practices that will improve safety and service for highway users. Members include the Federal Highway Administration, the American Association of State Highway & Transportation Officials, the American Public Works Association, the Foundation for Pavement Preservation, the National Institute for Certification in Engineering Technologies and a number of roadway construction trade associations.

NJDOT, J.H. Reid General Contractor and Parsons Brinckerhoff-FG Inc. faced the challenge of replacing the 250-ft drawbridge with a five-span, 500-ft bridge. The new U.S. Rte. 9 Bridge over Nacote Creek in Atlantic County, N.J., has a 25-ft vertical clearance and two new approach roadways. The new approaches were raised and realigned to correct and upgrade the bridge's vertical geometry, improve sight distance and eliminate an existing dip in the roadway.

From the beginning, interaction with the community was vital. During the early stages of project development, numerous community meetings were held. NJDOT also took many steps to alleviate community concerns about the initiative. For example, because traffic congestion was a major concern, a detour plan was designed that would have the least disruption to the community. The new bridge also was designed with visual enhancements that would fit in with the historic aesthetics of the area.

NJDOT worked with the New Jersey Department of Environmental Protection to protect the environment surrounding the project area, including marshes, wetlands and the Edwin B. Forsythe National Wildlife Refuge, and to lessen or eliminate detrimental effects from the construction. Wetland mitigation activities, for example, included creating high and low marsh tidal wetlands and establishing a turtle-nesting habitat for the diamondback terrapin turtles that inhabit the area.

To achieve a high-quality project, NJDOT also implemented a number of innovative design features that were a first for the agency. These features included using the Load and Resistance Factor design method and high-performance concrete for the bridge beams and the prestressed cylinder piles that support the pier caps. Nontoxic composite materials were employed for the bridge's fender system, which protects the bridge from collisions. Unlike the traditional chemically treated timber fender system, the new system will not leak toxins into the water. It also has a longer life expectancy. Other innovations used by the project were mechanically stabilized earth (MSE) walls and vibro concrete columns for the approach

Throughout the construction process, maintaining quality and safety was the subject of weekly "Tool Box" meetings held by project staff, where work activities planned for that week and work-zone safety measures were discussed.

embankments. The MSE walls were more economical and could be erected more quickly than cast-in-place walls. The use of MSE walls also reduced the amount of encroachment into wetlands in the areas around the abutments.

Throughout the construction process, maintaining quality and safety was the subject of weekly "Tool Box" meetings held by project staff, where work activities planned for that week and work-zone safety measures were discussed.

The bridge opened to traffic on Dec. 18, 2002, nearly two weeks early, and the final cost exceeded the contract amount by only 0.2%. Another hallmark of quality is that only two change orders were executed during construction. In addition, no accidents were reported during the entire time the project detour route was in effect. NJDOT's proactive approach to working with the local community also has paid off, as the new bridge has received a positive reception from residents and business owners.

The new bridge offers users a safer, smoother and better ride, while the innovative technologies employed will mean a longer performance life for the structure.

Merida is the division administrator in FHWA's New Jersey Division Office.

Reprinted from *Roads & Bridges,* January 2004.

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ASSET MANAGEMENT

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Asset Management
Working for You

by Dave Geiger

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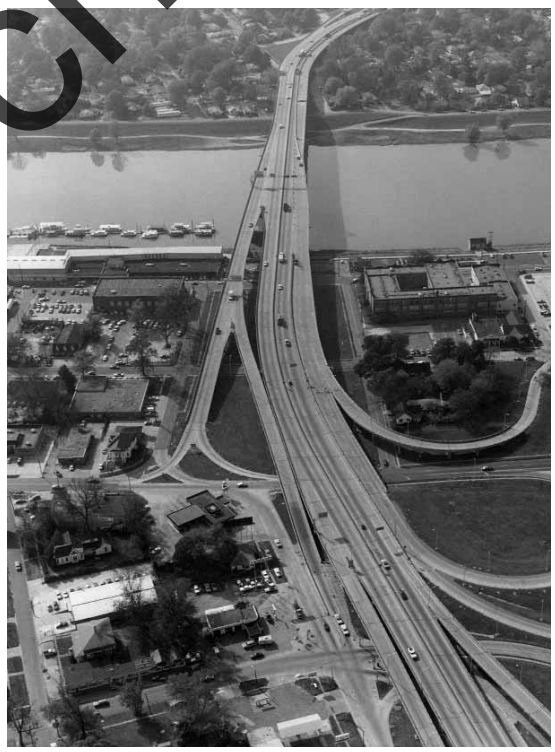
Making asset management work in your organization: the theme of the recent Sixth National Conference on Transportation Asset Management is also the continuing goal of the Federal Highway Administration's (FHWA) Office of Asset Management. As demonstrated at the November 2005 conference, asset management is working for an ever growing number of States, cities, and counties, both large and small. For example, in Washington, DC, the first tunnel management system designed for nationwide use is providing the city with a valuable tool for the future monitoring of the condition and performance of its highway tunnels (see May 2005 *Focus*). In Hillsborough County, Florida, a comprehensive asset management system for roadway and stormwater infrastructure has allowed the Public Works Department to target money more efficiently and better anticipate and respond to damage caused by hurricanes. And in States such as Kentucky, New Mexico, and New Jersey, FHWA's new Pavement Preservation Technical Assistance Program is partnering with their highway agencies to develop, expand, or improve pavement preservation programs to enhance the performance and extend the life of this critical asset.

Asset management is a strategic approach to allocating resources—dollars, people, and data—for the preservation, operation, and management of the Nation's transportation infrastructure. Through the use of management systems, engineering and economic analysis, and other tools, transportation agencies can more comprehensively view the big picture before making decisions as to how specific resources should be deployed. By strategically allocating resources, agencies can maximize the return on their investment, improve system performance, and increase customer satisfaction.

With asset management techniques and strategies becoming more visible and accepted nationwide, FHWA's Office of Asset Management continues its strong commitment to providing the training, tools, and deployment assistance needed to build on the progress made and continue advancing implementation efforts. The substantial progress to date means that every day, agencies are realizing improvements in safety, operations, system reliability, system condition, and financial performance. Over the past 2 years, for example, more than half of States have realized the benefits of accelerated highway construction by participating in the Accelerated Construction Technology Transfer (ACTT) program. At 3-day ACTT workshops, participants identify innovative approaches to reducing time, costs,



ACTT workshops have been held across the country, including one in Louisiana to accelerate the Monroe Bridge Rehabilitation Project on I-20.

and congestion for a planned highway project while improving safety, quality, and roadway performance. Most ACTT workshops have resulted in a reduction of planned construction time by 30 percent or more, with millions of dollars and years of delays shaved off of highway projects.

To help all of our State and local partners realize the benefits of asset management, we offer training and workshop opportunities that range from introducing asset management to highlighting specific asset management tools. A 1-day course available from FHWA's National Highway Institute (NHI), Transportation Asset Management, covers the principles, techniques, and benefits of asset management. Meanwhile, maintaining and preserving the Nation's $1.75 trillion investment in existing highway infrastructure assets is the focus of a series of four NHI courses on pavement preservation (see sidebar). When using asset management techniques to identify and evaluate resource allocation options, preservation is one of the most important considerations. Following a preventive maintenance strategy rather than waiting for roads to deteriorate before fixing them can extend the useful life of a pavement at a lower life-cycle cost than that of conventional pavement rehabilitation or reconstruction. The NHI workshops cover everything from selecting pavements for preventive maintenance to the different types of preventive maintenance treatments now available.

Training opportunities also include FHWA workshops on the Highway Economics Requirements System-State Version (HERS-ST) software program, life-cycle cost analysis (LCCA), and a new Web-Based Benefit/Cost Analysis Tool. The HERS-ST workshop provides a hands-on demonstration of the software, which is an asset management tool that can be used to analyze highway needs for programming and planning purposes. In the LCCA workshop, participants are introduced to LCCA concepts and the software program RealCost. The Web-Based Benefit/Cost Analysis Tool workshop introduces FHWA's tool for the application of benefit/cost analysis to a variety of roadway and intersection projects. All of the workshops are offered at no cost.

The Office of Asset Management also has case studies available that highlight highway agencies that are leading the way in implementing asset management programs. *Economics in Asset Management* details the experiences of Hillsborough County, Florida, in implementing a comprehensive asset management program for its roadway and

stormwater infrastructure. The new approach includes all of the forecasting elements necessary to do multiyear budgeting of maintenance, operations, and capital replacement of assets as needed. *Bridge Management*, meanwhile, highlights how California, Florida, and South Dakota are using the Pontis® bridge management system to more efficiently manage and maintain their bridges and achieve their agencies' performance goals. Case studies on *Data Integration* experiences in Arizona, Michigan, Pennsylvania, and Virginia are also available.

Looking at 2006 and beyond, FHWA will continue to develop new tools, technologies, and deployment strategies. As many State and local agencies are now active in implementing asset management in their day-to-day activities, FHWA will be promoting the further development of management tools, analysis methods, and research topics, including economic evaluation and trade off methodologies. It is important to consider strategies that emphasize communication and the sharing of information with policy and technical decisionmakers, as well as elected officials, on the benefits of applying asset management principles and techniques from the planning and initial goal setting process through the operations, preservation, and maintenance stages.

One of the new tools being developed is the rolling wheel deflectometer, which is a specially designed tractor-trailer that can measure pavement deflections while traveling at speeds up to 100 km/hr (70 mi/hr).

Also under development is a new workshop on data integration, which is designed to help highway

Archived

Resources

Online
To learn more about the Office of Asset Management's many resources and initiatives, visit www.fhwa.dot.gov/infrastructure/asstmgmt/.

Workshops
For more information or to schedule the following FHWA asset management workshops, see the contacts listed below.

- Highway Economics Requirements System-State Version (HERS-ST)—Robert Mooney, FHWA, 202-366-4657 (email: robert.mooney@fhwa.dot.gov)
- Life-Cycle Cost Analysis—Bernie Kuta, FHWA, 720-963-3204 (email: bernie.kuta@fhwa.dot.gov)
- Web-Based Benefit/Cost Analysis Tool and Economic Analysis for Highway Decisionmaking—Eric Gabler, FHWA, 202-366-4036 (email: eric.gabler@fhwa.dot.gov)

ACTT
Information on Accelerated Construction Technology Transfer (ACTT) is available at www.fhwa.dot.gov/construction/accelerated/. To learn more about holding an ACTT workshop in your State, to obtain a copy of *ACTT: A "How To" Guide for State Highway Agencies* (Publication No. FHWA-IF-05-038), or to obtain a copy of the 2005 status report on the ACTT program, *ACTT Now* (Publication No. FHWA-IF-05-039), contact your local FHWA division office. Information is also available from Jim Sorenson in FHWA's Office of Asset Management, 202-366-1333 (email: james.sorenson@fhwa.dot.gov), or Jerry Blanding in the FHWA Resource Center, 410-962-2253 (email: jerry.blanding@fhwa.dot.gov).

NHI Courses
To schedule the following NHI courses, contact Sherron Monts at NHI, 703-235-0534 (email: sherron.monts@fhwa.dot.gov).

- *Transportation Asset Management* (No. 131106)
- *The Preventive Maintenance Concept* (No. 131054)
- *Selecting Pavements for Preventive Maintenance* (No. 131058)
- *Design and Construction of Quality Preventive Maintenance Treatments* (No. 131103)
- *Pavement Preservation: Integrating Pavement Preservation Practices and Pavement Management* (No. 131104)

Case Studies
Economics in Asset Management (Publication No. FHWA-IF-05-024), *Bridge Management* (Publication No. FHWA-IF-05-040), case studies on data integration, and other previously completed case studies are available online at www.fhwa.dot.gov/infrastructure/asstmgmt/casestudies.cfm.

Archived

agencies consolidate their electronic data so that they can make better and more cost-effective decisions about managing their assets. Better managing data is also the goal of an ongoing effort to update the Pontis software program, which can be used by highway agencies to organize their bridge data and analyze complex engineering and economic factors.

We will continue to work with State and highway industry leaders through the National Partnership for Highway Quality to encourage the use of quality practices in highway planning, design, construction, and management to achieve the best value for our customers.

While the tools of asset management include data, software, and other state-of-the-art technologies, our ultimate focus is the driving public that we serve. Whether establishing bridge management systems to better analyze and use the data that we have or using accelerated construction techniques to complete needed highway projects faster and with less inconvenience to motorists, asset management is about using our resources more effectively to improve the driving experience and quality of life for our customers and our communities. Making asset management work in our organizations ultimately provides increased benefits to all of us.

Dave Geiger is the Director of FHWA's Office of Asset Management.

Reprinted from *Focus,* December 2005.

Formula for Success

by Jim Sorenson

Asset management equals oversight plus accountability, sound engineering, and economic decisionmaking.

Archived

Today's transportation agencies face significant pressures to handle more challenges with fewer resources. Traffic congestion is increasing, as is the need to preserve and enhance an aging infrastructure and address public frustration with travel delays and work zones.

The Federal Highway Administration (FHWA) is pursuing numerous avenues to improve the Nation's surface transportation system. State and local agencies have been traditional partners of FHWA in these efforts, and the newly passed highway legislation—Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)—institutes a number of new opportunities for partnerships with the private sector. By working together, solutions will be found, and public satisfaction with transportation programs should increase.

Whenever public dollars are used, governments are responsible for more than just keeping their constituents satisfied. Governments also must account for the use of the public's money and the resources devoted to the projects and programs under their direction. Agencies at every level of government have a responsibility to be good stewards of the transportation infrastructure and to maintain the public's trust and confidence that constituents do receive value for every tax dollar spent.

"Without public trust and confidence, the resources will not be made available to address the immense challenges that face the transportation community today and that we will continue to face in the future," says Acting Federal Highway Administrator J. Richard Capka.

FHWA plays a key role in protecting the Nation's transportation investments and has an overarching stewardship responsibility for managing federally funded programs efficiently and effectively. The stewardship includes effective management of public funds entrusted to the organization. FHWA accomplishes this stewardship by being a value-added leader, sharing innovations in technology, and providing sound technical advice and support to its State partners and stakeholders.

"Financial stewardship and accountability are embedded in all aspects of the agency's mission, both in headquarters and in field offices," says FHWA Executive Director Frederick G. Wright. "It is imperative that we ensure integrity in the expenditure of public funds through strong financial accountability and oversight."

Secretary of Transportation Norman Y. Mineta has confirmed that financial accountability is one of the top priorities of the U.S. Department of Transportation (USDOT). The recently issued Financial Integrity Review and Evaluation (FIRE) program documents how FHWA will take action to improve its financial management role. As indicated by Wright, "It is imperative that FHWA effectively evaluate the systems, controls, and procedures that are in place to protect the funds entrusted to the agency."

The FIRE program directs FHWA division offices to perform a number of reviews in support of the annual certification of financial controls to support the agency's financial statements. FIRE includes a toolkit that provides detailed information for implementation and contains review guides for the various processes to be reviewed. FIRE covers internal controls as well as Federal-aid funds management. Just as FHWA must meet the fiscal controls, it must ensure that the product being purchased with Federal dollars gives the expected performance. Looking at system performance and highlighting areas for further reviews is vital for construction program management.

Oversight, a primary element of stewardship, is key to meeting the public's expectations of quality in transportation projects. FHWA's oversight responsibility involves ensuring that the Federal-

Aid Highway Program is delivered in accordance with applicable laws, regulations, and policies. This responsibility incorporates minimizing the potential for waste, fraud, and abuse, as well as advocating the national values expressed in environmental laws, public participation requirements, and safety design standards.

FHWA's oversight methods have changed over the years as the emphasis has shifted from building new highways to preserving and enhancing the existing infrastructure. During that time, FHWA has developed resources and tools that State and local government partners can use to enhance their own oversight efforts.

FHWA's focus remains unchanged: working with its partners to ensure that Federal dollars achieve defined national goals and maintain the public's trust that its money is well spent.

"Our roles and responsibilities in the administration of the Federal-Aid and the Federal Lands Highway Programs have evolved in past authorizing legislation; however, the expectation that we maintain an appropriate level of oversight and accountability in those programs has been constant," Wright says.

Challenges for Today

Today's transportation agencies work in an era of increasing demands on budgets and staff resources. The transportation professionals responsible for oversight face a number of challenges in their day-to-day operations. One of the greatest challenges is meeting customers' expectations. In addition, Federal, State, and local departments of transportation (DOTs) all face similar staff reductions and budget challenges.

Contributing to the staffing challenge is the attrition of seasoned transportation and construction personnel. Many field engineers who were on the front lines during the major highway construction projects of the 1960s and early 1970s have retired, and many of today's transportation professionals have not had the opportunity to acquire as much experience in construction project management and oversight. As in the past, these field engineers are the eyes and ears for transportation agencies.

Despite the staffing challenge, the level of highway construction and hence oversight are not expected to decline. More roads than ever are operating near capacity, and an increasing percentage of highways have outlived their original design lives and now face needed rehabilitation or reconstruction. Yet there are fewer personnel to provide oversight on existing infrastructure enhancements and operational needs in addition to the oversight needed for development of new or reconstructed roads.

Requirements to preserve and enhance the aging infrastructure within budget parameters make it necessary for agencies to set priorities as to which of many critical projects to undertake now and which to postpone until another budget cycle. Although construction and rehabilitation projects are generally higher profile and, in the past, have received priority, today States are finding that a minimum (5 to 10 percent) investment in a dedicated preservation program is both improving the condition of roads and bridges in their jurisdictions and freeing up their budgets for the capital improvements desired.

In addition, the public continues to raise the bar on its expectations of the highway system. Although in the early days of highway construction, the priority was simply to have paved roads to get from farm to market, today the public demands a safe, efficient, long-lasting national highway system. Many industries depend on just-in-time delivery to minimize overhead costs and move products throughout the Nation and overseas. Given the new global economy, the ability of the United States to compete internationally is directly related to its capacity to move goods from the plains to the ports.

Along with the public's high expectations comes increasing frustration with growing traffic congestion and highway construction delays. FHWA's 2000 traveler satisfaction surveys found that 43 percent of respondents expressed dissatisfaction with traffic flow on major highways, up from 23 percent 5 years earlier. Thirty-two percent expressed frustration with work zones.

Overall, the Nation's highway program has become increasingly complex, with environmental commitments, urban planning needs, operational requirements, and budget and political pressures all vying for the limited time of transportation agency personnel and tight financial resources. Juggling construction, maintenance, public safety, and financing presents a definite challenge to every transportation organization.

Moving Forward on Oversight

In this challenging environment, FHWA's primary focus continues to be on stewardship and oversight to meet the public's expectations for quality—

Archived

including safety characteristics, operational efficiency, and durability—and accountability as guardians of the Nation's transportation system.

The focus involves working in partnership with State and local transportation agencies, which have similar stewardship responsibilities to the public for the transportation infrastructure under their management and the Federal tax dollars entrusted to them to operate their programs.

Today, FHWA's emphasis is on initiatives that concentrate on broad program areas because these focuses are more likely to yield systemic improvements and result in higher payoffs for the effort invested. FHWA conducts its oversight through a wide range of mechanisms, including process reviews, program evaluations, program management activities, and project involvement activities.

In years past, when FHWA's staffing level was nearly twice that of the 2005 level, engineers were actively involved in the oversight of numerous individual highway construction projects. Although there has been a shift from project oversight to program oversight, FHWA's responsibility to assure the proper use of Federal resources remains unchanged.

FHWA's evaluation of State and local transportation agencies' construction programs, for example, involves an assessment of State procedures and controls for assuring that transportation improvements are constructed in accordance with approved standards and contracting methods.

"We will be far more efficient if we focus on ensuring that the processes that produce project decisions are right, rather than trying to track each individual decision," FHWA's Director of Field Services-West Christine Johnson told attendees at the FHWA 2005 Western Area Engineer's Conference. "However, to be good program managers, we must not lose sight of the core skills needed to understand project decisions." Every process review requires a sampling of the projects to assure that the process is being followed and that it is effective at producing the product or activity desired.

Effective evaluation of management and financial issues is also key to oversight. An example that Johnson cited was focusing on getting the right materials for the roadway's asphalt mix, but losing the value of having the right materials because the construction project bid was off or the construction schedule was delayed because the funding was estimated incorrectly. "Those tend to be management issues rather than technical issues. Nevertheless, they are just as important," she said.

FHWA provides technical assistance in solving problems, recommends improvements to ensure high-quality construction, and shares information on innovations in materials, equipment, construction practices, and contracting methods. The recent success in carrying out the Accelerated Construction Technology Transfer program is an example of the leadership and technical support that FHWA can provide.

Inspections at the program level and on carefully selected projects are the primary methods that FHWA uses to fulfill its construction program oversight responsibilities. FHWA's objectives in conducting inspections include defining the progress and quality of work, identifying problem areas and innovations, documenting resolution of those problems, and sharing innovations and new technologies. The number and type of reviews conducted annually are determined by the FHWA division administrator's periodic risk assessment. This assessment takes into account the staffing and skills of the State DOT, program size and complexity, contractor and supplier availability, as well as FHWA division staffing and other factors.

FHWA conducts various types of inspections. Process reviews and product evaluations, for example, assure that State processes, procedures, and controls conform to Federal requirements. In depth inspections are detailed reviews to track the processes necessary to correct problems or promote processes that produce high-quality products on a project, district, or statewide basis.

The FHWA reviews generally confirm that the work is in reasonably close conformity to the plans and specifications or that certain areas might need future attention.

Reviewing Processes and Programs

Each FHWA division office is responsible for developing a construction management program that defines the types and frequencies of inspections needed to maintain a reasonable level of confidence in the construction program it oversees.

To help carry out its oversight responsibilities, the FHWA Illinois Division developed guidelines for conducting annual process reviews. Under the guidelines, available at www.fhwa.dot.gov/construction/cpmi04c2.htm, FHWA and the Illinois Department of Transportation (IDOT) jointly select five or six topics a year for review, establish review teams, and develop a purpose and scope for each review.

Archived

Topics of reviews conducted in 2005 included bridge expansion joints, construction program estimates, roadside safety assessments, environmental documentation, and the Chicago Department of Transportation's authorization process and construction documentation. "Process reviews are part of our continuous improvement process," says Eric Harm, IDOT deputy director and assistant chief engineer. "Working with FHWA on reviews gives us an extra set of eyes to take a look at our processes to see where we can improve them."

Joint coordinators from FHWA and IDOT head each review team, which can include representatives from other State and local transportation agencies affected by the review topic. Each team interviews staff in each IDOT district and reviews construction projects related to the topic. After the team completes the review, it holds a meeting with district staff to discuss what it observed and develops a report on its observations and recommendations for each district.

In addition, the team develops a statewide report that summarizes the results of the process review, documents observations that apply to the entire State, and outlines action items with specific deadlines to resolve or improve any problems it observed.

"What the Illinois process shows is that you can establish good partnerships with a State agency and make mutually beneficial progress," says Dean Mentjes, an FHWA Illinois Division mobility engineer who has participated on several review teams.

The Illinois reviews have resulted in a number of process improvements and specification changes over the years. Using cost and performance data collected during a review of bonded concrete bridge deck overlays a few years ago, the team produced guidelines and rewrote specifications on when to use different types of overlays and preoverlay treatments.

As a result, IDOT adopted new policies and is now obtaining better performance from bridge decks. "Anytime we can improve performance on something like a bridge deck, we ultimately save money by not having to rehabilitate it as often," says Harm.

FHWA's Washington Division develops annual performance reports on its construction project inspections, program evaluations, systematic reviews, and financial audits of the Washington State Department of Transportation (WSDOT). The reports describe the reviews conducted during the fiscal year and provide a synopsis of FHWA's findings. WSDOT, in turn, posts the FHWA reports on its "Accountability" Web site at www.wsdot.wa.gov/accountability/performance/default.htm and prepares media releases to demonstrate the accountability of its construction program to the public.

In addition, WSDOT State Construction Engineer Kevin Dayton cites FHWA's independent reviews of State projects as useful in providing feedback to the Washington State Joint Legislative Audit and Review Committee, which conducts performance audits of State programs. In one instance, when a committee member commented that she believed WSDOT did not have an adequate number of field staff, WSDOT officials replied that FHWA inspection reports indicated that the agency was doing a satisfactory job.

FHWA's California Division developed a program review/product evaluation (PR/PE) initiative, which it used during the 1990s and is now reviving. Program guidelines are available at www.fhwa.dot.gov/construction/cpmi04c1.htm. The program calls for annual evaluations of the adequacy of processes, procedures, and products used by the California Department of Transportation (Caltrans) in project development and construction activities.

These reviews can be broad in scope, covering a major activity or program such as conceptual studies or preliminary plan development for construction projects, or more specific, covering products or elements such as pavement design, safety features, materials quality control, or construction management. Based on the reviews, FHWA can determine whether a process is being implemented as intended and is producing the desired result.

Under the guidelines, the PR/PE team develops an annual schedule of reviews based on input from several sources, including the State DOT, FHWA headquarters, and trends found in other division offices. The effort is to identify national and statewide policy concerns, and to obtain Caltrans management input on high-risk or problem areas. The team also looks at data from past design reviews, construction inspection reports, and related activities.

In addition, the team reviews a list of special emphasis areas, which are potential major review elements for the PR/PE program. The list covers a multitude of phases in the development, design, and construction of Federal-aid projects—from seismic analysis and bridge design to project staffing and supervision.

Archived

The team uses a criteria assessment model to evaluate each potential topic to determine the need for a PR/PE review. Topic selection criteria include the level of Federal interest, technical complexity, the degree of concern, and the statutory requirements related to it.

Guide to Better Inspections

The guidelines developed in Illinois and California for process and program reviews and the positive working relationship found in Washington State and many of the FHWA division offices are just some of the many tools available for local and State transportation personnel to adopt and use in carrying out oversight activities.

The guidelines are included in FHWA's *Construction Program Management and Inspection Guide* (FHWA-IF-04-013), available online at www.fhwa.dot.gov/construction/cpmi04tc.htm. To help engineers improve their technical knowledge and select a balanced program of construction management techniques, the guide highlights proven techniques for construction inspections.

"The guide can familiarize newer staff members with the construction management and oversight process, as well as serve as a refresher for veteran engineers," says Jeffrey Lewis, field operations engineering team leader in the FHWA California Division and a member of the FHWA Construction Quality Improvement Team, which developed the publication.

In addition to being a resource for FHWA staff, the guide is useful for State and local staffs as they plan, construct, and monitor projects using Federal-aid funds, Lewis says. "They need to understand the FHWA philosophy and intent when they act on FHWA's behalf," he says. "The guide helps explain what that encompasses."

The guide discusses the steps necessary to implement an effective construction management program. The steps include defining the types and frequencies of inspections needed to assure a quality construction program, performing inspections and reviews, preparing and distributing reports, and following up on findings.

Among the tools in the guide is a checklist of items to consider when conducting an inspection, such as progress and quality of work, construction operations and features, project records, changes, and time extensions. The guide also contains an outline of the contents that a construction management report should incorporate, including details on observations, findings, resolutions, and quality management initiatives.

In addition, the guide has sample inspection report forms, such as bid review and design project checklists. Engineers can use the forms to streamline the writing process for reports and make them easy to follow.

The online version of the guide will be updated as new products, processes, guidelines, and sample reports become available that would benefit engineers carrying out oversight responsibilities. "It's designed to be an evolving document," says Lewis. "This is just one of the tools we have made available to assist our younger engineers and midcareer employees."

More Tools to Use

In addition to the *Construction Program Management and Inspection Guide*, FHWA has developed several workshops and maintains a number of Web sites that provide valuable information and tools for transportation professionals involved in construction management and oversight.

A National Highway Institute (NHI) workshop based on the *Construction Program Management and Inspection Guide* provides engineers and transportation specialists with proven methods and tools for performing effective construction oversight. The workshop covers the changing roles of FHWA's field staff and provides participants with an understanding of construction stewardship with an emphasis on construction inspection techniques. Another NHI workshop on Conducting Reviews That Get Results covers methods for planning construction reviews, collecting and analyzing data, presenting review results, and formulating recommendations that can be implemented successfully. Information on scheduling these workshops can be found at the following Web sites:

www.fhwa.dot.gov/construction/072904.htm

www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=1146

"One of the beauties of these workshops is that the instructors are a blend of FHWA staff from the Resource Center, division offices, and headquarters, so participants benefit from that interaction," says Lewis, a workshop facilitator and Construction

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Quality Improvement Team coleader. "By the time participants walk out of the class, they're ready to go to a project and be comfortable doing a review. We can't make up for years of experience [that] we as an agency have been losing the past 10 years, but with this workshop and the tools provided, we do add confidence to our newer employees."

Workshop facilitators encourage local, State, and Federal teams to attend sessions together and bring examples from upcoming reviews to discuss. "If we can include our State and local partners in a workshop, then when we perform reviews with them on the team we can all use the same tools and the same terminology and get the most out of the process review," says the FHWA Illinois Division's Dean Mentjes, who helps deliver the workshop.

NHI offers several other courses related to construction program management, including Drilled Shaft Foundation Inspection (13207A), Driven Pile Foundation Inspection (132069A), Safety Inspection of In-Service Bridges (130055A), Shallow Foundations (132037A), and Use of Critical Path Method (CPM) for Estimating, Scheduling, and Timely Completion (134049A). The NHI course catalog is available at www.nhi.fhwa.dot.gov/coursec.asp.

"What we get out of training workshops is the latest available information on a specific topic and any developments going on nationwide or even internationally that can help us do things better in Illinois," says IDOT's Harm.

The "Construction and Maintenance" Web site, maintained by FHWA's Office of Asset Management at www.fhwa.dot.gov/construction, provides an overview of resources and links, including highway construction specifications, Federal-aid construction program regulations, accelerated construction technologies, the latest memoranda and publications on construction and maintenance topics, and related research.

The "National Highway Specifications" Web site at www.specs.fhwa.dot.gov consists of a searchable library of highway specifications from across the country. This publicly available site is the result of a partnership between FHWA and the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Construction. The site also features discussion forums on the development and use of various types of construction specifications.

The "Generic Construction Related Review Guidelines" site at www.fhwa.dot.gov/construction/reviews.htm provides engineers with examples of reviews undertaken by FHWA field offices on topics such as asphalt pavements, bridge decks, right-of-way appraisal, and traffic control in work zones. These generic samples can be modified to meet specific program needs.

The "Construction Program Guide" site at www.fhwa.dot.gov/construction/cqit/index.htm features a list of links on construction topics such as advertising for bids, design-build contracting, quality assurance, safety, and warranties. The links, in turn, provide information on laws, regulations, policies, guidelines, and training on each topic.

Public Trust and Confidence

Just as the transportation community of 50 years ago faced the challenge of building a national interstate system, today's transportation community is looking at how to best use resources, protect the environment, reduce congestion, enhance safety, and increase the longevity of the infrastructure.

FHWA plays a major role in addressing these issues by promoting innovative practices and working with State agencies to find new solutions to highway problems. In addition, FHWA conducts oversight activities that assure the best use of taxpayers' dollars in meeting the needs of the traveling public. FHWA has an important role working with its State partners to manage public investment in the Nation's highway assets.

This renewed recognition of the need for construction oversight does not mean turning back the clock to more Federal oversight. Instead, today's emphasis is on working with State partners to ensure that the processes that produce project decisions are effective, rather than trying to track each individual decision.

FHWA's focus is on being proactive in meeting public expectations for quality and accountability and earning the public's trust and confidence as the guardian of the national transportation system.

"Agencies are charged with ensuring that the programs they oversee are conducted in a manner that best meets the public interest," says Acting FHWA Administrator Capka. "The public expects agencies to maintain the highest standards of integrity, demonstrate competence, make wise decisions, communicate openly and clearly, and meet commitments. By meeting those expectations, the agency earns the public's trust and confidence."

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Evolution of FHWA Oversight

The FHWA oversight role has changed over the years, but the agency's responsibility as the guardian of the national transportation system remains the same.

"Much of our oversight and approval for eligibility has been delegated to our State partners," said Christine Johnson, FHWA's director of field services-west, at the FHWA 2005 Western Area Engineer's Conference. "However, our accountability has not been delegated. We have a responsibility to verify that the processes and safeguards that a State is supposed to have in place are in place and are being followed."

From the early 1900s to the 1950s, FHWA's predecessor, the Bureau of Public Roads (BPR), used a partnership approach in which States administered Federal-aid highway projects and BPR made the checks necessary to protect the Federal interest. BPR was the main technical source for State and local agencies, and BPR field engineers stepped in frequently to solve complicated design and construction problems.

In 1956, the Federal-aid program expanded to build the national interstate system. From 1956 to 1974, authorizations under the Federal-Aid Highway Program increased more than 900 percent, while FHWA staff increased to an agency maximum of about 5,200 employees.

When a U.S. House of Representatives special investigative committee raised concerns in 1959 about a lack of construction quality and waste, fraud, and abuse in highway construction, BPR changed its oversight role and stepped up the level of project inspections. The focus of the division offices changed from providing advice to providing project-level actions that included detailed reviews and approvals. As the interstate construction program continued its rapid growth, and the State highway agencies gained experience and technical expertise, BPR began delegating some oversight responsibilities to the States.

By the early 1970s, FHWA (created when the U.S. Department of Transportation was formed in 1967) faced the dilemma of not being able to maintain its previous level of project reviews, despite its larger workforce. Meanwhile, FHWA was gaining confidence in the States' technical competence and ability to manage their own construction projects.

In 1973, Congress reduced the scope of Federal monitoring of Federal-aid highway projects on all but the interstate system. A 1974 FHWA study recommended a transition from project reviews to process and program reviews. Then-FHWA Executive Director R.D. Morgan initiated a stepped-up program of training in core areas and renewed emphasis on both program and project reviews, and division office program reviews and annual reporting was required.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) changed the Federal oversight role by giving States more authority to ensure that projects are constructed to expected quality levels and shifting the Federal role primarily to program-level oversight.

The Transportation Equity Act for the 21st Century (TEA-21) further delegated authority to the States by releasing oversight functions under agreement between FHWA and States. At the same time, TEA-21 increased Federal oversight for megaprojects, major construction projects with budgets that total more than $1 billion each.

A 2001 FHWA policy statement reaffirmed that, regardless of the project responsibilities delegated to States, FHWA is ultimately responsible for Federal highway programs. The policy emphasizes stewardship and oversight initiatives that focus on broad program and process reviews with project-specific verification.

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What Is Asset Management?

FHWA and AASHTO define asset management as "a strategic approach to managing transportation infrastructure. It focuses on . . . business processes for resource allocation and utilization with the objective of better decisionmaking based on quality information and well-defined objectives."

Asset management involves combining engineering principles with sound business practices and economic analysis to provide tools that facilitate an organized and logical approach to informed decisionmaking. Asset management provides a framework for both short- and long-term planning. It is about having a systematic process for maintaining, upgrading, and operating assets in a cost-effective way.

Implementation of asset management processes helps an organization use its available resources, human as well as financial, to provide customers with the most efficient and effective transportation system possible. The principles of asset management apply to all aspects of the program, from planning through project development, construction, operation, preservation, and maintenance.

Jim Sorenson, senior construction and system preservation engineer in FHWA's Office of Asset Management, is responsible for technical assistance, policy development, and research guidance in the areas of construction and maintenance, operations, transportation system preservation, asset management, and quality management. During his three-decade career, Sorenson has worked in a variety of assignments in FHWA field and headquarters offices and participated in a number of FHWA initiatives, including the Superpave Technology Delivery Team, the Strategic Highway Research Program's Highway Operations Technical Working Group, and the Integrated Mobility and Safety Team. He has a bachelor's degree in civil engineering from Montana State University.

Reprinted from *Public Roads,* November/December 2005.

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ACCELERATED CONSTRUCTION

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ACTT Now

Join the accelerated construction bandwagon. Over the past 2 years, more than half of States have realized the benefits of accelerated highway construction by participating in the Accelerated Construction Technology Transfer (ACTT) program. Started by the Transportation Research Board, American Association of State Highway and Transportation Officials, and the Federal Highway Administration (FHWA), ACTT brings State highway agency staff together with national experts in a range of skill sets for a 3-day workshop. At the workshop, participants identify innovative approaches to reducing time, costs, and congestion for a planned highway project while improving safety, quality, and roadway performance.

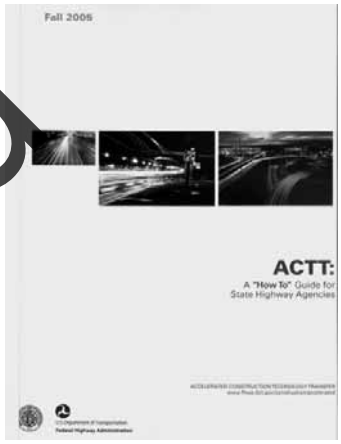
Over the course of the workshops to date, millions of dollars and years of delays have been shaved off of highway projects, with projects ranging in size from those with $1 million budgets to those projected to cost more than $2.5 billion. Most ACTT workshops have resulted in a reduction of planned construction time by 30 percent or more.

All States can now join in the success of ACTT by holding their own accelerated construction workshops, with the assistance of their FHWA division offices and the Accelerated Construction Management Team (ACMT). This team will help States plan, organize, and carry out workshops, which are now eligible for Federal-aid funding. "The ACMT will help States incorporate ACTT into select major reconstruction and rehabilitation projects, boosting the rapid transfer of fresh technology solutions, minimizing risk, and potentially saving construction time and dollars,"says Jim Sorenson of FHWA's Office of Asset Management and a member of the ACMT. "Our goal is to spare motorists and communities from any avoidable construction-related traffic disruption, while helping agencies deliver state-of-the-art roadways that meet the demands of our increasingly mobile society."

Over the course of the workshops to date, millions of dollars and years of delays have been shaved off of highway projects, with projects ranging in size from those with $1 million budgets to those projected to cost more than $2.5 billion.

Factors to consider in selecting an ACTT project include:

- Does the project involve major reconstruction and/or rehabilitation work that will begin over the next 4–6 years?
- Is there an urgent need to accelerate construction?
- Are the project limits or boundaries still fluid?
- Is the project team open to innovation and willing to consider and apply fresh concepts?



To assist States in planning an ACTT workshop, a new publication is available from FHWA, *ACTT: A "How To" Guide for State Highway Agencies* (Publication No. FHWA-IF-05-038). The guide includes background information on the ACTT program and details on how to plan and hold a workshop. Also included are sample workshop agendas and lists of the various ACTT skill sets and their team leaders. Skills sets cover such areas as design, contracting, financing, construction, right-of-way/utilities, and the environment. The ACMT will maintain a

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national roster of skill set experts and assist States in setting up a skill set team for a workshop.

During the next few years, the ACMT will be working with States who have held an ACTT workshop and are now moving their ACTT project or corridor into the construction phase. ACTT workshop recommendations will be tracked to see which ones are actually implemented and how much is actually saved in time and costs. "We are committed to making the ACTT process a standard business practice for highway agencies on major reconstruction or rehabilitation projects," says King W. Gee, FHWA's Associate Administrator for Infrastructure. "Demonstrating real-world results is essential for the success of this effort."

Additional information on ACTT, including articles and reports on workshops held to date, is available at www.fhwa.dot.gov/construction/accelerated. To learn more about holding an ACTT workshop in your State, to obtain a copy of the ACTT "How To" Guide, or to obtain a copy of the 2005 status report, *ACTT Now* (Publication No. FHWA-IF-05-039), contact your local FHWA Division Office. Information is also available from Jim Sorenson in FHWA's Office of Asset Management, 202-366-1333 (fax: 202-366-9981; email: james.sorenson@fhwa.dot.gov), or Jerry Blanding in the FHWA Resource Center in Baltimore, Maryland, 410-962-2253 (fax: 410-962-4386; email: jerry.blanding@fhwa.dot.gov).

Reprinted from *Focus*, October 2005.

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Teaming Up to Accelerate Lake Washington's Floating Bridge Project

Washington State Route 520 (SR 520) is one of only two major State highways running east-west between Seattle on the west side of Lake Washington and the communities of Bellevue, Redmond, and Kirkland on the east side of the lake. Designed for an average daily traffic of 65,000 vehicles, the road now carries between 110,000 and 120,000 vehicles daily and is often congested for 13 hours on weekdays. A March 2004 workshop in Seattle looked at ways to accelerate the replacement of SR 520's 40-year-old Evergreen Point floating bridge across Lake Washington. The workshop was held by the Washington State Department of Transportation (WSDOT) and the Accelerated Construction Technology Transfer (ACTT) team sponsored by the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials.

One of the oldest floating bridges in the world, the Evergreen Point Bridge is reaching the end of its useful life. Not only is its capacity inadequate, but it is vulnerable to storms and seismic events. The bridge's pontoons are subject to cracking and leaking and its low position in the water makes it susceptible to high, crashing waves during storms. With an estimated cost of between $1.5 and $3.4 billion, depending on the number of lanes selected for the new bridge, funding for the project is a challenge. There has also been concern expressed by communities on both sides of the bridge about the proposed construction and its impact. Three project alternatives—a four-lane, six-lane, and eight-lane bridge—are currently being evaluated by WSDOT. Also being evaluated are the use of tolls to help fund the project.

The ACTT workshop brought together local and national transportation experts from State highway agencies, industry, academia, and FHWA. These experts' skill areas included design, construction, structures, traffic/safety/intelligent transportation systems, innovative contracting and financing, environment, and right-of-way. Dan Mathis, Division Administrator for FHWA's Washington State Division Office, noted that, "This workshop is about meeting the customers' needs during and after construction. It's about being creative. Our role is 'To get in there, do the work and do it right, and then get out of the way.'" Building on these concepts, the goals of the workshop included:

- Shorten construction time
- Minimize construction impacts
- Identify options for construction staging
- Develop creative financing strategies
- Maximize maintenance of traffic flow
- Encourage contractor innovation and involvement.

Rick Smith, WSDOT's Innovative Project Delivery Director, and other WSDOT staff introduced workshop participants to the complicated urban project and gave them a tour of the project site. Participants met in smaller skill set groups to brainstorm ideas and develop recommendations for meeting the project goals. These recommendations included using a design-build contract to shorten the overall project delivery time by overlapping design with construction. Also suggested was segmenting contracts, such as replacing the bridge in four separate segments. In addition, employing prefabricated bridge construction was recommended as a means of accelerating the project, including the use of precast substructures, deck panels, and superstructures. In the area of materials, it was suggested that self-consolidating concrete (SCC) be used, particularly for the construction of the bridge's pontoons. Because of the large quantity of concrete necessary and the anticipated depths of the pontoons, the use of conventional concrete would be

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very labor intensive. SCC flows easily and can completely fill intricate and complex forms under its own weight, eliminating the need for vibration.

Other workshop recommendations included breaking the pontoon fabrication into separate contracts, depending on the type of work; designing the bridge's simple pontoons first so that they can be constructed while the more complex pontoons are still being designed; and building "lids" over the roadway first and then using them for construction access and traffic staging. Also stressed was the importance of coordinating with other regional projects, as there are several other mega projects being proposed in the area. Among the financing options, participants recommended looking at the benefits of starting toll collection on SR 520 earlier than originally planned to raise additional funds.

"Participants were fully engaged and creative and brought new information and ideas to the table," noted Maureen Sullivan, Project Director in WSDOT's Urban Corridors Office. "The recommendations present a great opportunity for saving 1–2 years in construction time." Depending on the availability of funding, WSDOT tentatively plans to begin construction on the new bridge in 2008.

To learn more about the SR 520 Bridge Replacement Project, visit www.wsdot.wa.gov/projects/SR520Bridge, or contact Maureen Sullivan at WSDOT, 206-381-6436 (email: SullivM@wsdot.wa.gov), or Julie Meredith at WSDOT, 206-381-6406 (email: MeredJL@wsdot.wa.gov). For more information on ACTT, contact Dan Sanayi at FHWA, 202-493-0551 (email: dan.sanayi@fhwa.dot.gov). Information is also available online at www.fhwa.dot.gov/construction/accelerated or through your local FHWA Division Office. An ACTT workshop will be held this month in Oklahoma, with workshops also scheduled in Minnesota (June), Wyoming (September), Rhode Island (October), New Jersey (November), and Nevada (March 2005).

Reprinted from *Focus,* May 2004.

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Project Pegasus

TxDOT Accelerates the Reconstruction of Dallas Interstate

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With the population of Dallas, Texas, expected to double over the next 20 years, the Texas Department of Transportation (TxDOT) faces the challenge of providing the transportation infrastructure that will support that growth. Their answer? Project Pegasus. This initiative aims to transform the two major Interstate freeways that serve downtown Dallas, redesigning portions of IH 30 and IH 35E.

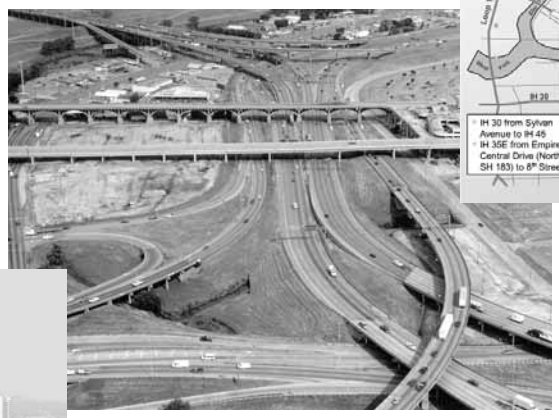
As part of an American Association of State Highway and Transportation Officials and Federal Highway Administration (FHWA) initiative known as Accelerated Construction Technology Transfer (ACTT), a workshop was held in Mesquite, Texas, from September 9–11, 2003, to focus on strategies for accelerating the 19.3-km (12-mi) Project Pegasus. The workshop brought together local and national transportation experts from State highway agencies, industry, academia, and FHWA. These experts' skill areas included design, construction, innovative financing, right-of-way, utilities, innovative contracting, the environment, work zone traffic control, and worker safety.

The portions of the IH 30/IH 35E freeways being rebuilt as Project Pegasus are critically congested, with bumper-to-bumper traffic occurring for more than 6 hours a day and traffic speed averaging only 32 km/h (20 mi/h). The traffic problems are exacerbated by the outdated layout of the freeways, which were primarily designed in the 1950s to take travelers to downtown Dallas. Travel patterns have changed over the decades, however, and today four out of every five drivers remain on the freeways and bypass downtown Dallas. Design standards have also changed over the years: In many locations on the freeways, ramps lack adequate acceleration or deceleration lengths, interchanges and ramps are too close together, and bridges have limited vertical and horizontal clearances, among other problems.

The reconstruction project will add capacity, with plans calling for five to six lanes in each direction and one or two reversible high-occupancy vehicle (HOV) lanes in the median. Operations and safety will also be improved by upgrading to meet today's design standards for freeways, as well as by eliminating left hand merges and diverges.

The goal of the $760 million Project Pegasus is to complete the reconstruction work in 4 years, versus the original estimate of 7 years. Other goals are to:

- Maintain traffic with minimal disruption.
- Accommodate special events in the region.
- Provide access to emergency facilities.
- Maintain a safe work zone.
- Minimize construction delays due to right-of-way, utilities, and railroad issues.
- Incorporate a context-sensitive design into project plans.



Project Pegasus will transform the two major Interstate freeways that serve downtown Dallas, IH 30 and IH 35E.

Don Lucas of the Heritage Group and chair of the Transportation Research Board (TRB) Committee A5T60, the Task Force on Accelerating Innovation in the Highway Industry, noted that customers are demanding a response to their travel needs. "The momentum is building for change. We need to share innovative practices and processes with each other to create a new picture of how we can perform high-speed construction while maintaining the quality."

"Acceleration is a priority topic for DOTs," added Hal Kassoff of Parsons Brinckerhoff and also a member of the TRB task force.

Tim Nesbitt, project manager for TxDOT, noted that challenges faced by TxDOT in accelerating the project include having to weave construction around railroad tracks, major employment sites, four city parks, the Dealey Plaza historic district, American Airlines Center, and a new proposed stadium site for the Dallas Cowboys.

Workshop participants met in smaller skill set groups to brainstorm issues and ideas and develop recommendations for meeting the project goals and working through the challenges. Recommendations for accelerating the project included using design-build contracting to optimize innovation, coordinating with utility companies early in the project planning process, and using long-life pavements with a 50-year design life. Other recommendations included employing construction techniques for structures that minimize the traffic impact, such as incremental launching, lateral slide, and heavy lift methods; improving general materials specifications to only allow use of premium materials; using contractor incentives to minimize traffic disruption; and setting up a dedicated incident management system at the project site.

Additional traffic management suggestions included constructing the planned Trinity Parkway west of I-35E prior to this project, so that mainline traffic can be detoured onto the Parkway. This will enable such traffic strategies as total or partial road closure, weekend closures, or restricting road use to HOV vehicles only, to be used. The importance of providing information to the public was emphasized, as workshop participants noted that real-time traveler information should be provided and that project work should be supported by intensive media efforts to let residents and the community know about the changes taking place.

The AASHTO/FHWA ACTT team is developing a report on the workshop and will then compile 6-month and 1-year follow-up reports detailing which of the workshop recommendations were implemented and to what extent.

Support for the ACTT initiative is steadily gaining momentum. The next workshop will be hosted by the California Department of Transportation in December. Louisiana, Montana, Oklahoma, and Washington State have all indicated that they are interested in hosting workshops in 2004, while States such as Georgia, Idaho, Maryland, Massachusetts, Minnesota, New Jersey, and Wisconsin have also expressed interest in the ACTT program.

To learn more about Project Pegasus, contact Brian Barth at TxDOT, 214-320-6189, or visit the project Web site at www.projectpegasus.org. For more information on ACTT or to learn more about hosting a workshop in your State, contact your local FHWA Division Office or Dan Sanayi at FHWA, 202-493-0551 (email: dan.sanayi@fhwa.dot.gov).

Reprinted from *Focus*, October 2003.

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Asphalt's Generation of Change

by Tom Kuennen

Perhaps nothing in the road industry has changed more in the past two decades than asphalt pavement technology.

Now well into the 21st century, the asphalt paving industry is light years from what it was just a generation ago.

But if a generation is defined as the interval between the birth of parents and the birth of their children, those light years actually are only about 20 years.

In those two decades the industry has been transformed from being a producer of a dependable, but plain-vanilla product for overlays and low-volume roads, to a producer of an environmentally friendly, high-tech paving medium adaptable to different climates, traffic loads, end-use applications, and suitable for recycling and reclamation.

And it's all happened on our watch.

Consider these near-tectonic shifts in hot-mix asphalt that have occurred in just two decades:

- The industry has shifted from conventional Marshall mix designs, based on a binder's viscosity or resistance to penetration, to performance-related, more durable Superpave binder mix designs.
- That shift has spawned a new generation of lab and field mix-testing equipment and new full-scale accelerated pavement testing facilities, and it has supported a new class of technically trained lab technicians. One result of this is a tremendous, growing body of data that is being used every day to make mix design decisions and improve long-term asphalt performance.
- Complementing Superpave, new, extremely rugged mix designs like stone matrix asphalt (SMA) have been imported from Europe and elsewhere to benefit highway agencies and their motorist patrons.
- The chemistry of liquid asphalt has been enhanced by a new generation of asphalt modifiers, boosting the performance of Superpave mixes (Superpave Plus), open-graded friction courses, and thin-lift overlays.
- Abetted by innovative new equipment and research, recycling of reclaimed asphalt pavement and other industrial or waste materials into pavements now has spread through the asphalt paving establishment, benefiting the environment and reducing costs.
- The industry has adapted to most of its work being done on existing rights-of-way and accommodating ever-growing traffic loads by embracing night work as a standard way of doing business.
- Major changes in state department of transportation staffing and philosophy have put more responsibility with the contractor for quality assurance and quality control. These changes have also compelled contractors to offer long-term warranties for their work, and have forced them to develop new equipment and new ways of providing the super-smooth pavements that taxpaying motorists want.
- While infrared and electronic technology improve quality and placement of mix, new asphalt paver designs permit faster, safer, and more versatile paving.

"In my time, hot-mix asphalt has changed dramatically," said National Asphalt Pavement Association 2003 chairman Peter A. Wilson, senior vice president of Barriere Construction LLC, in his inauguration address. "We have had our own evolution and revolutions. Today, we know so much more about our product and its characteristics than we did 25 years ago."

In 2003, the industry knows how to design a pavement that will not rut, and one that holds up to the heaviest traffic, the Louisiana contractor said, adding today's asphalt pavements are smoother, quieter, more cost-effective to maintain, and longer-lasting than ever before.

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"We have all these things going for our industry because we have a new and improved product, a product much different and much better than we have ever had," Wilson says.

Durable Mixes

The number-one change over the last 20 years has been the rise of more durable asphalt mixes and the advent of performance-related binder specifications under the Superpave system of asphalt mix design.

No other development in HMA in the past generation has had so much impact in so many areas of the asphalt industry as the advent of Superpave.

Superpave—a registered trademark of the Transportation Research Board—was a product of the Strategic Highway Research Program, authorized by Congress in 1987.

And while Superpave launched the modern era of asphalt paving, Superpave itself was launched with the 1984 Transportation Research Board Special Report 202, *America's Highways: Accelerating the Search for Innovation*, also known as the Strategic Transportation Research Study or the STRS ("Stars") report. This report laid the foundation of the Strategic Highway Research Program, which gave birth to Superpave.

Under the guidance of an expert steering committee, STRS settled on six areas of study in which focused, accelerated, results-oriented research promised significant benefits.

Foremost was asphalt, with an objective of improving "pavement performance through a research program that will provide increased understanding of the chemical and physical properties of asphalt cements and asphalt concretes," STRS said.

The other research topics were long-term pavement performance, the cost-effectiveness of maintenance, protection of concrete bridge components [from chlorides], cement and concrete in highway pavements and structures, and chemical control of snow and ice on highways.

STRS recommended a radical increase in research funds—to the tune of $150 million over five years—funded by 0.25% of federal-aid highway funds. The American Association of State Highway & Transportation Officials, representing all state departments of transportation, agreed to a 0.25% "take-down" from the federal-aid highway funds, and the Strategic Highway Research Program was born.

Superpave is Performance-Based

Superpave is a performance-based system of specifications for designing asphalt pavements to hold up to the traffic loading and weathering stresses of the new century.

The three major elements in the Superpave system are an asphalt binder specification geared to pavement loading and local climate, a volumetric mix design and analysis system, and mix analysis tests and a performance prediction system that include computer software, weather database, and environmental and performance models.

Superpave's volumetric properties include the percentage of air voids, voids in the mineral aggregate, and voids filled with asphalt. Superpave allows civil engineers to fine-tune asphalt mixes to specific traffic loads and climates, thus producing pavements that are more durable and less likely to rut in extremely hot weather or to crack in extremely cold weather.

Switch to Superpave

The Marshall system of mix designs served well from World War II, but under the crushing loads of modern traffic, had to be reconsidered.

"If there was a single problem with asphalt in the 1980s, it was rutting," said Gerry Huber, P.E., research engineer, Heritage Research Group, at the Superpave 2003 conference, held March 17-19 in Nashville. "Rutting became a national epidemic in the 1980s. If you look in the trade press, in the technical journals you will see there was a huge amount of emphasis placed on rutting of asphalt pavements."

The rutting of the 1980s was different than much of the rutting of the past, he said. "This rutting was occurring within the mixture itself, not structural rutting," Huber said. "Rutting had tended to be a structural process, in which the subgrade or granular layers underneath the pavement were giving away, with a gentle settlement in the pavement causing the rut in the wheel path. Here, a shallow rutting was taking place, in which the upper 3 or 4 inches of HMA were rutting, with sideways displacement of the mix in the asphalt layer itself."

To fix required a new approach toward rutting. The existing penetration grading of asphalt binders dated to the 1890s, and derived from the force required for a physical push of the thumb, and later, No. 10 sewing machine needle, to make a displacement at the top of a barrel of asphalt.

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"In the 1970s we decided we should get a lot more sophisticated than the penetration test, and we began to look at viscosity penetration," Huber said. "We began to develop devices to measure the viscosity of asphalt instead of penetration."

But both specification methods had a common drawback: They only measured how stiff the asphalt was at a certain temperature. "They didn't tell anything about the properties of the asphalt at other temperatures," Huber said. "Asphalt's stiffness properties are affected by temperature and time of loading. SHRP was tasked with coming up with performance-based specifications for asphalt binder, mix design, and aggregates. SHRP addressed rutting, fatigue cracking, and low temperature cracking."

At the start of 2003, 47 states included Superpave specifications as a standard specification, if not the only spec allowed, for state DOT paving. The University of Texas at El Paso found that for the 2002 construction season, the most recent reliable data available, 4,726 scheduled projects were designed using Superpave procedures.

That's triple the number of Superpave projects built in 1998 and about 60% of the state asphalt paving projects scheduled for letting in 2002. Superpave has become the national standard.

Asphalt Modifiers Boost Performance

While additives to asphalt have been promoted since the days of the asphalt "patent mixes" of the 19th century (for this purpose, 1871–1918), the specialized asphalt modifiers of the last two decades have improved asphalt performance, and made possible designs such as open-graded friction courses and thin-lift overlays.

And today modifiers make it possible to improve lower-performing performance-graded asphalt binders to the point where they can meet stringent PG specifications for Superpave mixes. The performance properties of asphalt modifiers for Superpave work now are being studied and publicized by the Federal Highway Administration under its Superpave Plus program.

"Modified asphalt binders are typically used in high stress applications," says FHWA's John D'Angelo, P.E. "They have been used in intersections with stop-and-go traffic, high-volume truck routes, and high-volume interstates. Modifiers have also been used in extreme climate conditions to reduce aging in desert climates and to help produce binders for extreme low-temperature applications."

OGFCs were abandoned in the 1970s and 1980s because the liquid asphalt was not stiff enough, creating drain-down of asphalt into dense "fat" spots, while encouraging raveling of the top layer of aggregate. Today's polymer-modified asphalt mixes are mixed at higher temperatures, thus more efficiently drying the aggregate in the drum and improving adhesion.

Modifiers developed over the last 20 years include:

- Styrene butadiene rubber, "latex." SBR stiffens the binder and can improve adhesion and cracking resistance. It is usually added at a minimum rate of 3% by weight of binder.
- Styrene-butadiene-styrene. SBS polymer increases stiffness, crack resistance, and adhesion of the binder, and is added at a rate of 3 to 5% by weight of binder.
- Ethyl vinyl acetate. EVA polymer boosts stiffness and cracking resistance at temperatures above freezing, but doesn't provide good low-temperature cracking resistance.
- Crumb rubber modifiers. CRM, added at less than 20% by weight of binder, are used with great success. The crumb rubber is blended with asphalt cements at elevated temperatures ("wet" process) and improves resistance to cracking. A "dry process" adds the crumb rubber as an aggregate in the drum.

RAP Becomes Part of Industry

The energy crisis of the late 1970s led to another tremendous change in the way asphalt is manufactured and placed—the adoption of reclaimed asphalt pavement specifications.

When the Arab Oil Embargo and subsequent energy crisis triggered skyrocketing oil prices and petroleum conservation programs, aged asphalt pavement changed from a waste material destined for landfills to a valued product to be stockpiled and reused in many ways.

But it would not have been possible without the refinement of the cold milling machine.

"By the mid- to late-1970s, high-horsepower cold milling machines took over and became an integral part of the rehabilitation process," said

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NAPA president Mike Acott in late 2001. "The operation was seamless, and best of all it could be done under traffic. It restored the [road] profile and traffic could ride on the milled surface."

In 2003, RAP is commonplace; it is reused as inexpensive road base, added to virgin hot-mix asphalt as a tested material, used for driveways, bike paths, recreational trails, and much more.

Asphalt pavement is unquestionably the nation's most widely recycled product. A 1993 study by the FHWA and EPA says about 73 million of the 91 million tons of asphalt pavement that are removed each year during resurfacing and widening projects are reused as part of new roads, roadbeds, shoulders, and embankments. That's a recycling rate of 80%.

The 73 million-ton volume of recycled asphalt pavement is about one-third higher than the total volume of 60.7 million tons of post-consumer recycling. And it's double the volume of paper, glass, plastic, and aluminum combined, the FHWA/EPA reports.

Use of RAP also saves valuable aggregate resources. While there are plenty of construction aggregates in place in the ground, there are fewer and fewer aggregate sites that are permitted for extraction.

Existing quarries or gravel pits once outside of a city now are being surrounded by new suburbs—and neighbors who don't like living near quarries and will fight any kind of expansion.

But RAP contains aggregates that have already been acquired, permitted, shot, loaded, crushed, screened, stockpiled, reloaded, and hauled, saving time, money and resources.

And reclaimed asphalt pavement isn't the only product recycled in asphalt pavements or below them. Others include reclaimed demolition portland cement concrete as base material; crumb rubber from old tires, added to asphalt pavement or reused as bases for temporary traffic signs, traffic cones, or in rubber railroad crossing pads; crushed, rounded broken glass as a mineral aggregate in asphalt; waste sand from metal-casting foundries; reclaimed asphalt roofing shingles; and in California, crushed toilets in road base.

Full-Scale Testing

The performance of Superpave, SMA, RAP, and different types of aggregates are being tested year after year under real-world conditions at a variety of full-scale, accelerated testing facilities.

These facilities have included MnRoad in Minnesota, WesTrack in Nevada, and most recently, the Pavement Test Track of the National Center for Asphalt Technology.

MnROAD. The Minnesota Road Research Project is the world's largest and most comprehensive outdoor pavement laboratory, distinctive for its electronic sensor network embedded within 6 miles of test pavements. Located 40 miles northwest of Minneapolis/St. Paul, its design incorporates 4,572 electronic sensors. The sensor network and extensive data-collection system provide opportunities to study how heavy, commercial truck traffic and the annual freeze/thaw cycle affect pavement materials and designs. Unlike WesTrack and NCAT, MnROAD is not exclusively devoted to HMA research.

WesTrack. As Superpave unfolded, the Federal Highway Administration became involved in developing performance-related specifications for HMA. Its first major step was the construction and loading of a test track in Nevada, WesTrack, near Reno. The WesTrack Road Test was conducted from 1996 to 1999. Its purpose was to evaluate the direct effects of deviations of materials and construction properties on pavement performance. WesTrack was a 1.8-mile oval track divided into 34 test sections. The track was loaded over a two-year period using driverless vehicle technology. Test results provided useful information in areas such as quality control/quality assurance, construction methods, pavement rehabilitation, and materials specifications. But WesTrack had its critics. Some experts felt the driverless vehicles did not provide a real-world effect of wear on the pavement surface. The computer-controlled trucks continuously traveled in the same wheel path causing extreme wear in that path.

NCAT. Today, NCAT's Pavement Test Track is attempting to answer some of the questions raised at WesTrack.

In 1986, members of NAPA endowed the National Center for Asphalt Technology at Auburn University, providing a centralized, systematic approach to asphalt research. In 2000 NCAT opened a new research center and 1.7-mile test track and is now the world's leading institution for asphalt pavement research.

The first phase of testing at NCAT's track incorporated 46 sections, averaging 200-feet long, each of a different permutation of asphalt mix or lift design, as specified by one of the co-sponsoring state DOTs, or by the Federal Highway Administration.

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In mid-December 2002 the NCAT Test Track ended a two-year cycle in which 10 million equivalent single axle loads—equal to 1.6-million miles—were logged on the track using professional drivers.

Among the findings after two years: Negligible rutting of the performance-based binder sections took place in test sections, and that occurred mainly during the first summer. Rutting decreased in the second summer, and stopped after the seven-day average high air temperature was below 82 degrees F. The small amount of rutting observed probably was related to "densification," or long-term compaction of mix under traffic.

In October 2003, following reconstruction work, the NCAT track was to resume its experimentation. Reconstruction in summer 2003 included milling and inlaying 14 sections with new rutting study mixes, and deep removal of eight sections to facilitate a small, instrumented structural experiment. Truck traffic will continue on the remaining sections to extend the original 2000 experiment over a second application of design traffic (for example, another 10 million ESALs).

Demands Won't Stop

As asphalt has gotten bigger, better, and more complex, and the work environment more complicated, the state DOTs and taxpaying motorists have benefited. From the point of view of the contractor and asphalt supplier, though, the challenges have gotten harder and more costly. Unfortunately, that's a cycle that's not going to stop. Fortunately, America's asphalt contractors have pledged themselves to setting the pace and not stopping the improvement.

"The asphalt pavement industry has demonstrated an ongoing commitment to quality improvement and product innovation," says NAPA's Acott. "It's the versatile pavement that meets every customer's specific needs."

Reprinted from *Better Roads,* November 2003. *Better Roads* can be visited online at www.BetterRoads.com.

Perpetual Pavement Launches a New Chapter in Asphalt Design

Perpetual Pavements are designed with thick layers of asphalt of different mix types, with a sacrificial driving course on top. This driving or friction course is intended to be periodically cold-milled and overlaid to restore the ride quality and surface friction.

Perpetual Pavements are designed and built from the bottom up, with a lower layer designed to resist bottom-up fatigue cracking. The middle layer uses an asphalt mix designed to support anticipated traffic loads, and the top layer may be customized to local conditions and requirements, from SMA for high-volume urban interstates, to OGFC for noise reduction and safety, to Superpave for other applications.

"We now have the capability of designing the most cost-effective mix using local materials, selecting the appropriate mix type for the traffic conditions and environment," says NAPA's president Mike Acott. "Through an understanding of the interrelationships between material characterization, pavement thickness, fatigue, and rut resistance, we are able to develop Perpetual Pavement structural designs that result in the lowest life cycle cost."

Promotion of Perpetual Pavement designs continues, and each year the Asphalt Pavement Alliance recognizes long-performing, existing pavements which meet Perpetual Pavement design criteria with the Perpetual Pavement Award.

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Innovations in Hot-Mix Asphalt

by David Newcomb

The era of innovation started with recycling, moved to Superpave and SMA, and might just get us to roll-your-own roads.

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Competition demands product improvement through innovation to achieve an advantage in terms of quality, cost, and convenience. The hot-mix asphalt industry has answered the call of competition with innovations that better match materials and mixtures to their applications, and with manufacturing techniques and technology that produce these products in the most environmentally friendly manner possible.

And these innovations have been cost effective. The cost of the product must be the lowest it can be while ensuring that performance expectations remain at their highest. Likewise, the long-term costs of maintenance and rehabilitation need to be minimized in order to justify the selection of the product.

At one time, contractors were essentially told what to do and how to do it. The expertise in dealing with hot-mix asphalt resided primarily in the various agencies that specified asphalt, and the contractor provided the equipment and personnel to build the project.

But, beginning in the 1970s, the industry began to change its way of doing business by recycling asphalt. The oil crisis of that period made recycling very advantageous. Not only was it saving asphalt cement, it was saving aggregate, energy, landfill space, and just as importantly, it was saving money. Agencies wrote specifications allowing the contractor to retain ownership of the material and decide how much recycled material, within reason, to put into the new mix. This innovation has become a hallmark of the industry and asphalt is America's most recycled material as a result.

As the 1970s started to give way to the 1980s, agency concern over asphalt pavement performance led to intensive efforts to improve specifications and mix design processes, and to tailor mixes to specific circumstances. The introduction of quality control/quality assurance and end-result specifications in this period began the shift of responsibility to the contractor. As a result, contractors increased their knowledge of the product and saw the genuine economic benefits of reduced reliance on method specifications.

New Mix Designs

Late in the 1980s, the Strategic Highway Research Program started as an initiative by the state highway agencies through the American Association of State Highway and Transportation Officials. By 1993, a new asphalt binder specification and a new mix design procedure had been put in place by means of the Superpave system. In the 10 years since, many refinements have been made and continue to be made to simplify the procedure, to remove redundant requirements, and to improve performance. These refinements were the direct result of the asphalt industry working with AASHTO and individual agencies through the Binder and Mixture Expert Task Groups. The major missing piece of the Superpave system, a suite of performance tests, is about to be completed through National Cooperative Highway Research Program Project 9-19.

About the same time that Superpave was being developed, a joint industry-agency scan tour of Europe was made under the auspices of the Federal Highway Administration to investigate technology that might be of benefit to the U.S. That trip introduced the industry to a new type of hot-mix asphalt —Stone Matrix Asphalt. As a surface mixture, SMA had a proven record of rutting and cracking resistance under heavy traffic. The combination of a strong aggregate structure with a binder-rich matrix proved to be a winning recipe for high volume roadways. States such as Georgia, Maryland, Wisconsin, Illinois, Louisiana, Texas, and others now specify

SMA as their premium surface mixture. Illinois plans to further this innovation by developing an SMA for low-volume roads.

Experimentation with open-graded friction courses began in the 1960s as a way of improving the skid resistance of pavements. Implementation took place in areas where they were successful, and further refinements to the mix design process were made. In the last couple of years, the new generation of open-graded friction-course materials and mix design were brought over from Europe and standardized at the National Center for Asphalt Technology. These mixes are more porous and more durable than their predecessors. These improvements are taking place just as greater benefits and more uses are being identified for the new generation OGFC.

Another benefit of OGFC-surfaced pavements is they vastly improve visibility in rainstorms by reducing the amount of splash and spray generated by traffic. Furthermore, OGFC surfaces greatly reduce the amount of pavement-tire traffic noise, an increasingly important benefit to landowners adjacent to highways.

The National Center for Asphalt Technology at Auburn University has been an important part of the change in the way asphalt mixtures are tested. They developed the NCAT oven, which allowed for the determination of mix asphalt content while eliminating the need to dispose of solvents. NCAT has played a central role in the refinements of the Superpave system, and provided the industry and agencies with guidance on mix design procedures for SMA and OGFC. The test track has answered questions regarding the rutting performance of surface mixtures and it will be key in the evaluation of new structural pavement design procedures.

Equipment Advances

Construction equipment and practices have also changed in an effort to improve the quality of the product, speed of construction, and production rates.

The invention of the milling machine ranks high in this category because it allows resurfacing to be done accurately and quickly. Additionally, it serves to reduce the number of steps in recycling the material by essentially sizing it before it goes to the plant.

Remixers and material transfer devices improve the smoothness of the roadway and minimize mix segregation.

Improvements in paver screeds, automatic screed controls, and rollers have also raised the bar on the quality of the HMA placed in the field, and engineering controls have been placed on paving machines to reduce fumes in the work environment.

In the future, contractors will have access to rollers that show the quality of compaction as they proceed down the pavement, and this will be tracked using global positioning technology.

HMA plants have also advanced, especially in terms of environmental friendliness. New plants incorporate innovations that make them run quietly, efficiently, and with fewer emissions.

The notched wedge joint was developed in Michigan over a concern for safety. This innovation allows contractors to place an overlay in one lane and not have to pull the other lane even before opening the road to traffic. This reduces construction time, costs, and improves smoothness.

Other innovations in longitudinal joints include joint tape and sealers which are applied to unconfined joints to improve joint performance.

Innovative Methods

Not all innovation is the result of broad sweeping changes in mix design, pavement design, or construction. Some of it is just people doing their jobs to meet the demands of the situation or the demands of specific requirements.

For instance, sometimes a road must get built when it's rainy or cold, and contractors have shown they can deal with it. On the New Mexico Highway 44 project, for example, contractors FNF and E.L. Yeager both used pavement heaters in the fall in order to keep the operation going. The construction management group of Koch Performance Roads noted that the heaters were an effective means of maintaining good paving conditions during cool weather and were crucial to the early delivery of the project.

Lakeside Paving in Seattle uses a trailer-mounted jet engine with the exhaust directed at the pavement to dry wet surfaces before paving. This improves the bond between the old and new layers and keeps the new mix hot, which gives them more opportunity to obtain density.

When confronted with a functional requirement of meeting a light reflectivity specification in a tunnel in France, Colas used waste from a mirror production plant in the surface of the roadway to provide the needed result.

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Future Innovation

There are further innovations in HMA technology occurring now and on the horizon which will respond to the needs of the future transportation system.

For instance, Perpetual Pavements, which are already gaining acceptance, will provide agencies with the means to reduce the life-cycle cost of owning a pavement and minimize user delay by having a long-lasting structure that only requires periodic resurfacing.

Porous asphalt pavements will present developers and land owners an alternative to current stormwater management practices by reducing runoff and providing groundwater recharge underneath parking lots meeting the proper criteria. Facilities using porous asphalt have been in use for up to 25 years of service, and they're still performing. NAPA has just released IS-131, *Design, Construction and Maintenance Guide for Porous Asphalt Pavements* to help designers and contractors who are interested in building porous pavements.

New methods of producing HMA will actually reduce the heat required by using warm-mix technology. Processes are being developed in Europe to reduce the mixing and compaction temperatures of HMA in order to reduce fumes and the energy required to make the mix. This technology will be showcased at the 2004 World of Asphalt Show and Conference, March 16 -18, in Nashville.

What's next? Asphalt you roll out like a carpet? Don't laugh, it's been done in the Netherlands as a part of their "Roads to the Future" project!

We are in a transition where responsibility for the final product is shifting from agencies to contractors. In the pursuit of providing a quality product that is economical and environmentally friendly, the industry is coming forward with numerous ideas and approaches to coping with the realities of construction and delivering the best possible performance.

David Newcomb is vice-president, Research and Technology, at the National Asphalt Pavement Association.

Reprinted from *Better Roads*, November 2003. *Better Roads* can be visited online at www.BetterRoads.com.

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Advancing the Future of Concrete Pavement Technology

After 5 years of research into improved technologies and methodologies for concrete pavement construction, the Federal Highway Administration's (FHWA) Concrete Pavement Technology Program (CPTP) continues to provide valuable new tools for transportation engineers and planners.

More than 30 research projects centered around 6 focus areas have been initiated under CPTP. These focus areas are: advanced pavement design, improved concrete materials, improved construction processes, repair and rehabilitation, workforce training, and enhanced user satisfaction.

One of the new products resulting from the CPTP research is the *Guide for Curing of Portland Cement Concrete Pavements* (Publication No. FHWA-RD-02-099). The guide was developed to help pavement engineers anticipate and correct potential curing problems associated with specific concrete materials properties, mixture proportions, and job site conditions. It looks at the many variables that influence the curing process and recommends steps to evaluate and control concrete moisture and temperature under different conditions. The guide is available from the National Technical Information Service at 800-553-6847 or 703-605-6000 (email: info@ntis.gov; Web: www.ntis.gov). The publication will also soon be available online at www.fhwa.dot.gov/pavement/pub_listing.cfm.

Also being developed are test protocols to aid highway agencies in identifying potential problems caused by material incompatibility before concrete is placed. These difficulties can include early stiffening, air entrainment problems, loss of workability, lower than expected strength and durability, and unexpected cracking at early ages. "In recent years, some cases of early-age problems and premature deterioration have resulted from use of incompatible concrete materials," says Shiraz Tayabji of Construction Technology Laboratories, Inc. (CTLGroup), and a member of the CPTP Implementation Team. "As concrete mixture proportions become more complex, the likelihood of incompatibility among materials increases with the number of ingredients added to the mix. The problem is compounded because not much has been known about the factors that lead to incompatibility, and tests have been lacking to determine the susceptibility of materials combinations to distress mechanisms," notes Tayabji. The new test protocols and compatibility guidelines will be available later this year. They will enable material suppliers, concrete producers, and users to:

- Identify combinations that adversely affect the early-age properties of concrete,
- Evaluate the uniformity of individual materials from the same source, and
- Optimize combinations for improved early-age performance.

Looking at the future, CPTP has developed a *Long-Term Plan for Concrete Pavement Research and Technology* (Publication No. FHWA-HRT-05-047). This 7- to 10-year Concrete Pavement Road Map incorporates input from more than 100 stakeholders across the country. It combines 250 research problem statements into 12 research tracks, including "Long-Life Concrete Pavements," "High-Speed Rehabilitation and Construction," and "Performance-Based Mix Design System." According to Tayabji, the Road Map will set the direction and agenda for concrete pavement technology improvements over the next decade. "The Road Map is grand in vision, but very practical in the manner that it addresses the technological gaps that need solutions. The implementation of the plan, based on strong partnering between public agencies and industry, will revolutionize the way we do pavement research in the United States," he says. The plan is

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available online at www.fhwa.dot.gov/pavement/pccp/pubs/05047/index.cfm. A two-volume report with details on the plan will be published shortly and will be posted online at www.fhwa.dot.gov/pavement/pub_listing.cfm.

Highway agencies and Local/Tribal Technical Assistance Programs can call upon CPTP for state-of-the-practice presentations and workshops on advanced concrete pavement technologies. Presentations can be arranged upon request for State, regional, and industry-sponsored workshops; onsite training sessions; and conferences (see sidebar). The specific topics to be featured and the format and length of the workshops can be tailored to meet the needs of each State or local area. Many of the products developed through CPTP are also available for field demonstration and CPTP-developed and validated test equipment is available to highway agencies on a loan basis from FHWA.

For more information on CPTP products and implementation activities, or to schedule a workshop/presentation or field demonstration in your State or region, contact Sam Tyson at FHWA, 202-366-1326 (email: sam.tyson@fhwa.dot.gov), or Shiraz Tayabji at CTLGroup, 410-997-0400 (email: stayabji@ctlgroup.com). CPTP information is also available online at www.fhwa.dot.gov/pavement/concrete.

Pore water is extracted from a mortar sample as part of CPTP's research into incompatible concrete materials.

CPTP Presentation Topics

- Long-Life Portland Cement Concrete (PCC) Design Features
- Rapid Repair and Rehabilitation
- Best Practices for Concrete Pavement Construction
- Design, Construction, and Repair of Whitetopping
- High-Performance Concrete Mixtures for Pavements
- Pavement Texturing Recommendations for PCC Pavements
- Measuring Pavement Smoothness for Acceptance on Concrete Pavements
- Construction Management Tools
- Concrete Durability Issues
- Optimizing Pavement Joint Details
- The CPTP Program

CPTP Workshops

- Concrete Pavement Best Practices
- Optimizing Paving Materials and Mix Design
- Best Practices for Concrete Pavement Construction
- Best Practices for Thin and Ultrathin Whitetopping

Reprinted from *Focus,* August 2005.

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Achieving Concrete's Full Potential

by Theodore R. (Ted) Ferragut, Dale Harrington, and Marcia Brink

The CP Road Map represents a long-term plan for research and technology development for PCC pavements.

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For most of the 20th century, engineers used the same tried-and-true materials in designing concrete pavements—portland cement, high-quality aggregate, and water—with only minor refinements. "Designers used a fairly forgiving formula that allowed minor variations in subgrade quality, construction practices, and other variables, without sacrificing pavement performance," says Director Tommy Beatty of the Office of Pavement Technology at the Federal Highway Administration (FHWA).

During much of that time, the industry enjoyed the luxury of keeping traffic off the new pavements for several days, even weeks, while the concrete developed its internal strength. Over the last 15 years, however, the industry has experienced more changes than in the previous 80 years, turning the process of building concrete pavements on end, Beatty says.

Today's concrete mix designs, for example, need to integrate a multitude of new materials—including fly ashes and chemical admixtures like water reducers, retarders, and accelerators—which can cause challenges in compatibility and reduce the tolerance for variations in aggregate moisture content, materials temperatures, weather conditions, and other variables.

In addition, motorists are more demanding, tolerating only minimal closures and delays due to roadwork and increasing the need for new paving methods that enable crews to get in, get out, and stay out. And motorists want smoother and quieter pavements, which is pushing the paving industry to exercise greater control on the characteristics of the road surface.

Increasingly, highway agencies are shifting their focus from building new pavements to rehabilitating and maintaining existing ones, which requires different designs, systems, materials, and equipment. Environmental pressures, as well, affect mix designs and construction practices, as crews work to reduce traffic congestion and manage drainage and runoff.

Further, highway budgets are being squeezed at every level, and the pavement community simply must do more with less. "In this environment, the old system for constructing concrete pavements simply does not work anymore," says Beatty. "To achieve concrete pavement's full potential in this changing world, the industry cannot continue business as usual."

To help the industry grow and meet the challenges of the 21st century, FHWA, Iowa State University, and many other partners collaborated to create the Long-Term Plan for Concrete Pavement Research and Technology. Dubbed the CP Road Map, the plan represents a comprehensive and strategic approach to research that will guide investment over the next several years and spawn a new generation of concrete pavements.

What Is the CP Road Map?

"The CP Road Map gives the concrete pavement community an opportunity to proactively reinvent itself through research," says Peter A. Kopac, research highway engineer at FHWA.

By combining more than 250 research problem statements into 12 fully integrated, sequential, and cohesive tracks of research, the project team expects that the CP Road Map will lead to specific products that will dramatically affect the way that concrete pavements are designed and constructed. The innovative track structure and cross-track integration will at once help the research teams focus on their designated tasks and effectively share information where tasks overlap.

A project team led by Iowa State University prepared the CP Road Map on behalf of FHWA, with backing and participation from stakeholders in the

concrete pavement industry, State departments of transportation (DOTs), and academia.

"In a very real sense, the authors of the CP Road Map include hundreds of stakeholders from State DOTs, materials supply companies, construction contractors, research and technology transfer universities, and other organizations," Kopac says. "For the men and women who face the daily realities and challenges of constructing and maintaining concrete pavements, this is their CP Road Map."

The project stakeholders will pool their resources to jointly conduct and coordinate the research, and an innovative implementation strategy will help move useful new products and systems into the field quickly.

Drawing a New Map

The Iowa State University-led project team facilitated development of the CP Road Map through a deliberate and inclusive process. First, the team created a "living" database of existing research, cataloging recently completed and inprogress projects and their products. Regularly updated and maintained, the database will serve as a valuable resource for many years.

Next the team gathered face-to-face input from the highway community, identifying research gaps that would become the basis for problem statements. The Iowa team hosted five brainstorming and feedback sessions at major industry events: the October 2003 meeting of the Midwest Concrete Consortium in Ames, IA; a special November 2003 regional workshop for eastern and southern stakeholders in Syracuse, NY; the May 2004 meeting of the American Concrete Pavement Association in Kansas City, MO; a special January 2004 regional teleconference for western stakeholders; and, in October 2004, a final meeting of national stakeholders hosted by FHWA at the Turner-Fairbank Highway Research Center in McLean, VA.

Through these events, plus presentations at more than 20 professional conferences and workshops across the country, more than 400 engineers and managers provided direct input into the CP Road Map. In addition to the organizations noted earlier, other participants included representatives from FHWA, State and local DOTs, the Portland Cement Association, the American Association of State Highway and Transportation Officials, the National Ready Mixed Concrete Association, Transportation Research Board and National Cooperative Highway Research Program committees, the American Public Works Association, the National Association of County Engineers, contractors, materials suppliers, universities with departments conducting applied research, and private concrete-testing laboratories.

The project team asked the participants to provide their insights in four broad categories: mixtures and materials, design, construction, and pavement management and business systems. Again and again, the stakeholders reported that they need improved analysis tools for measuring performance at every stage of the pavement system. They need to understand how and why pavements fail or succeed. Because variables in each stage affect the others, the methods and tools need to be integrated across stages, from mix and materials to design and construction, and with pavement management and business systems.

Based on these concepts of pavement performance and systems integration, the team proposed the following overall goal for the CP Road Map: By 2015, the highway community will have a comprehensive, integrated, and fully functional system of concrete pavement technologies that provides innovative solutions for customer-driven performance requirements.

Research Tracks

With abundant input from industry stakeholders and a strategic goal in hand, the project team identified dozens of specific research objectives and filtered them through the database of existing research to identify where gaps exist. The gaps became the basis for the 250 problem statements, which were added to the research database as work to be accomplished.

Team members organized the problem statements into 12 product-focused research tracks, which together form the long-term research plan. This structure captures the integrated, cross-category nature of the research and encourages stakeholder groups to step forward as champions for specific tracks. Research in one track often affects or is affected by research in another track, so team leaders for each track are responsible for ensuring that research is coordinated and integrated appropriately.

In addition to the defined tracks, the team leaders can sort information in the research database to isolate problem statements on a variety of subjects. Several problem statements, for example, are cross-

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referenced in multiple tracks, including those related to foundations and drainage systems, maintenance and rehabilitation, and advancements in environmental strategies.

Each of the 12 tracks is a complete research program in itself, with its own budget, two to seven subtracks, and as many as 20 problem statements. Tracks 1 through 9 consist of timed sequences of research leading to particular products that are essential to reaching overall research goals. Tracks 10, 11, and 12 are not phased because timing is not as critical.

One subtrack in every phased track is devoted to training tools and methods of technology transfer to ensure that innovative research products move into practice quickly and efficiently. The team defined the primary research tracks as follows:

1. *Performance-Based Mix Design System*. The final product of this track will be a practical yet innovative procedure for concrete mix design with new equipment, consensus target values, common laboratory procedures, and full integration with both structural design and field quality control—a lab of the future. This track also lays the groundwork for the concrete paving industry to assume greater responsibility for mix designs as State highway agencies move from method specifications to more advanced acceptance tools. For this move to be successful, the concrete paving industry and owner-agencies need a single document for the state of the art in mix design.

2. *Performance-Based Design Guide for New and Rehabilitated Concrete Pavements.* Under this track, the research community will expand the mechanistic approach to restoration and preservation strategies for concrete pavements, which involves using a structural response model to calculate pavement responses due to applied traffic and environmental loads. The track builds on and continues to develop the models created under the comprehensive National Cooperative Highway Research Program (NCHRP) Project 1-37A: Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures. The work in this track will be closely integrated with track 1.

3. *High-Speed Nondestructive Testing and Intelligent Construction Systems.* This track will develop high-speed, nondestructive quality-control systems to monitor pavement properties continuously during construction. As a result, workers will be able to make on-the-fly adjustments to ensure the highest quality finished product that meets given performance specifications. Many problem statements in this track relate to both tracks 1 and 2.

4. *Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements.* This track will result in improved understanding of the surface characteristics of concrete pavements. The research will provide tools to help engineers meet or exceed predetermined requirements for friction, safety, tire noise on pavements, smoothness, splash and spray, wheel path wear (hydroplaning), light reflection, rolling resistance, and durability (longevity). Each of these functional elements is critical. The challenge is to improve one characteristic without compromising another, while continuing to protect the safety of the public.

5. *Equipment Automation and Advancements.* This track will result in process improvements and the development of high-speed, high-quality concrete paving equipment to meet the concrete paving industry's projected needs and the traveling public's expectations for highway performance in the future. Examples include the next generation of concrete batching and placement equipment; behind-the-paver equipment to improve curing, surface treatment, and jointing; mechanized ways to place and control subdrains and other foundation elements; equipment to remove and replace the slab in one-pass construction; improved repair processes that decrease the time of operations and provide the workforce and traveling public with less exposure; and methods for evaluating new equipment on actual construction projects.

6. *Innovative Joint Design, Materials, and Construction*. Potential products for this track include a new joint design, high-speed computer analysis techniques for joint performance, a more accurate installation scheme, and faster rehabilitation strategies. The problem statements address the basics—joint design, materials, construction, and maintenance activities. The track also specifies research that will help develop breakthrough technologies and techniques for extremely high-speed joint repair. The team designed track 6 as a crosscutting track to

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ensure that all topics related to innovative joints are addressed. Much of the proposed research will develop important incremental improvements.

7. *High-Speed Rehabilitation and Construction.* To help develop faster techniques and higher quality for tomorrow's pavements, this track addresses a number of activities: the planning and simulation of high-speed construction and rehabilitation, precast and modular options, and fast-track construction and rehabilitation techniques for concrete pavement. The track also covers the evaluation and technology transfer of products and processes for high-speed construction and rehabilitation developed through research. Tracks 1 and 3 will likely involve the investigation of high-speed construction issues, so the CP Road Map project team will closely coordinate those efforts with track 7.

8. *Long-Life Concrete Pavements.* The need for longer lasting pavements that maximize the time between maintenance, restoration, or rehabilitation activities underlies all of the tracks in the CP Road Map. Track 8, however, draws attention to specific research that may lead to pavement life that approaches 60 years or more.

9. *Accelerated and Long-Term Data Collection.* This track provides the infrastructure—including data collection and reporting tools and testing methods—for a future national program that will plan accelerated loading and long-term data needs, construct test sections, and collect and share data. The problem statements in this track will identify the most useful data and determine the amount of time needed to collect that data.

10. *Performance of Concrete Pavements.* This track addresses key elements of pavement and asset management systems to determine whether pavements meet the performance characteristics that highway agencies and users desire. Research will determine and address the functional aspects of performance, particularly factors such as tire noise on pavements, friction, and smoothness. Research also will examine ways to schedule improvements to surface characteristics and conditions. Developing feedback loops in highway agencies' pavement management systems will be crucial to monitor performance quickly and effectively.

11. *Business Systems and Economics.* Roles and responsibilities are changing within the highway industry, affecting the way paving projects are designed, bid, built, and maintained. Increasingly State DOTs are asking contractors to assume greater control of the operation and quality-control inspections. By including warranty provisions in project contracts, owner agencies are asking for additional assurance that contractors are building pavements that will perform as expected. Many European countries like Spain and Great Britain have made dramatic changes in project funding methods and in the roles of contractors and suppliers. Track 11 captures important research that the industry needs to consider as this process of transformation continues in the United States. Problem statements cover contracting options, new technology transfer systems, public-private partnerships, and economic models.

12. *Advanced Concrete Pavement Materials.* The problem statements in this track address the development of new materials and refine or reintroduce existing advanced materials to enhance performance, improve construction, and reduce waste. Many of the existing materials studied in this track have been used only on a small scale or in laboratory evaluations. Many of them have not been used in the United States but show promise based on work completed in other countries. Track 12 will experiment with such materials on a larger scale and develop standards and recommendations for their use. The research will foster innovation in the development of additional new and innovative materials for constructing concrete pavements.

Reaching the Destination

Finally, the CP Road Map project team developed a management plan that outlines a progressive, cooperative approach to managing and conducting the research in the long-term plan. Under the management plan, participating organizations identify common interests, partner with one another to leverage funds and human resources, and execute specific contracts.

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The research management plan is based on several assumptions. First, the CP Road Map is a national research plan for FHWA, State agencies, and industry, and it is not restricted to any single funding source. "Publicly financed highway research is decentralized and will probably remain so," says Director Dennis Judycki of the Office of Research, Development, and Technology at FHWA. "In a decentralized arena like research, it is critical for stakeholder groups to come together voluntarily. Federal, State, and industry research staff and engineers around the country are looking for more opportunities to pool their funds and other resources in win-win situations."

Under the management plan, communication, technology transfer, and outreach activities will avoid the all-too-common disconnect between research results and implementation. "Technology implementation must be elevated to the same level of importance as research itself," Judycki adds.

Finally, managing the CP Road Map effectively and judiciously will require full-time, dedicated personnel with adequate resources. The CP Road Map project team, therefore, developed a governing structure in the research management plan that outlines a four-tiered system of participation and responsibility.

A three-party executive advisory committee, representing FHWA, State DOTs, and industry organizations, will provide broad oversight. The executive advisory committee will serve as a decision- and policymaking entity and will have the following responsibilities:

- Assembling team leaders for each research track
- Promoting partnering arrangements
- Ensuring adequate integration of research across tracks
- Developing and implementing a strategy to ensure that software products developed through various research tracks will be compatible with each other
- Identifying new program areas for research
- Overseeing updates to and maintenance of the research database
- Developing a comprehensive program for technology transfer and training for products created through the CP Road Map
- Developing a communications effort to keep the CP Road Map and its products in front of stakeholders and the public
- Conducting self-evaluation studies
- Keeping the momentum focused on outcomes, not just output

An administrative support group will provide professional management services for the executive advisory committee. The administrative group will coordinate and support activities like maintaining the research database.

Team leaders for the research tracks will coordinate and oversee all activities within specific research tracks, such as validating and updating the track, developing broad problem statements into specific research projects, identifying organizations to conduct or partner in the research, and ensuring proper integration of work within the track and across track lines.

Finally, sustaining organizations, which include highway agencies, consultants, universities, professional associations, and other organizations that have specialized interests and skills and are interested in pooling dedicated funds, will assume responsibility for conducting research through cooperation, partnerships, and funding agreements. Sustaining organizations may retain full fiscal and technical control of the work under their jurisdictions.

Future Steps

FHWA intends to implement the roadmap in cooperation with all partners and stakeholders. The CP Road Map project team likens a long-term research program to turning an oceanliner around. The process involves a long, slow sweep. In this case, the team has turned the rudder—the CP Road Map—in the right direction. The next step is to fire the engines, full speed ahead.

"We see the CP Road Map as a living document that will help all of us—FHWA, the States, the concrete paving industry, and other stakeholders—work together to make the most of our investments in concrete pavement research," says Cheryl Allen Richter, technical director of pavement research and development in the FHWA Office of Infrastructure Research and Development. "We look forward to working with stakeholders throughout the concrete paving industry to maintain the Road Map and—more importantly—fire up those engines to get the research underway."

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Research Tracks, Subtracks, and Estimated Budgets*

1. Performance-Based Mix Design System ($29.8M–$67.8M) Subtracks:
   - PCC Mix Design System Development and Integration
   - PCC Mix Design Laboratory Testing and Equipment
   - PCC Mix Design Modeling
   - PCC Mix Design Evaluation and Implementation

2. Performance-Based Design Guide for New and Rehabilitated Concrete Pavements ($40.5M–$59.6M) Subtracks:
   - Design Guide Structural Models
   - Design Guide Inputs, Performance Models, and Reliability
   - Special Design and Rehabilitation Issues
   - Improved Mechanistic Design Procedures
   - Design Guide Implementation

3. High-Speed Nondestructive Testing and Intelligent Construction Systems ($19.6M–$41.1M) Subtracks:
   - Field Control
   - Nondestructive Testing Methods
   - Nondestructive Testing and Intelligent Control System Evaluation and Implementation

4. Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements ($25.4M–$54.25M) Subtracks:
   - Concrete Pavement Texture and Friction
   - Concrete Pavement Smoothness
   - Tire-Pavement Noise
   - Integration of Concrete Pavement Surface Characteristics
   - Evaluation of Products for Concrete Pavement Surface Characteristics
   - Implementation of Concrete Pavement Surface Characteristics
   - Other Concrete Pavement Surface Characteristics

5. Equipment Automation and Advancements ($25.65M–$56.15M) Subtracks:
   - Concrete Batching and Mixing Equipment
   - Concrete Placement Equipment
   - Concrete Pavement Curing, Texturing, and Jointing Equipment
   - Concrete Pavement Foundation Equipment
   - Concrete Pavement Reconstruction Equipment
   - Concrete Pavement Restoration Equipment
   - Advanced Equipment Evaluation and Implementation

6. Innovative Joint Design, Materials, and Construction ($10M–$15.3M) Subtracks:
   - Joint Design Innovations
   - Joint Materials, Construction, Evaluation, and Rehabilitation Innovations
   - Innovative Joints Implementation

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7. High-Speed Rehabilitation and Construction ($10.3M–$20.3M) Subtracks:
    - Rehabilitation and Construction Planning and Simulation
    - Precast and Modular Concrete Pavements
    - Fast-Track Concrete Pavements
    - Rehabilitation and Construction Evaluation and Implementation

8. Long-Life Concrete Pavements ($10.5M–$16.6M) Subtracks:
    - Pavement Strategy for Long-Life Concrete Pavements
    - Construction and Materials for Long-Life Concrete Pavements and Overlays
    - Long-Life Concrete Pavement Implementation

9. Accelerated and Long-Term Data Collection ($9.75M–$15.5M) Subtracks:
    - Planning and Designing Accelerated Loading and Long-Term Data Collection
    - Preparation of Data Collection/Testing Procedures and Construction of Test Road
    - Implementation of Accelerated Loading and Long-Term Data Collection

10. Performance of Concrete Pavements ($2.7M–$4.15M) Subtracks:
    - Technologies for Determining Concrete Pavement Performance
    - Guidelines and Protocols for Concrete Pavement Performance

11. Business Systems and Economics ($21.15M–$31.2M) Subtracks:
    - Concrete Pavement Research and Technology Management and Implementation
    - Concrete Pavement Economics and Life Cycle Costs
    - Contracting and Incentives for Concrete Pavement Work
    - Technology Transfer and Publications for Concrete Pavement Best Practices
    - Concrete Pavement Decisions with Environmental Impact

12. Advanced Concrete Pavement Materials ($11.45M–$23.25M) Subtracks:
    - Performance-Enhancing Concrete Pavement Materials
    - Construction-Enhancing Concrete Pavement Materials
    - Environment-Enhancing Concrete Pavement Materials

$216.8M-$405.2M total (estimated)

*All numbers are rounded.

Source: Long-Term Plan for Concrete Pavement Research and Technology: The CP Road Map, An Executive Summary (draft), www.pcccenter.iastate.edu/publications/task15/pc_road_map_execsumm.pdf.

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Concrete Pavement Technology Program Introduces New and Improved Tools for Pavements

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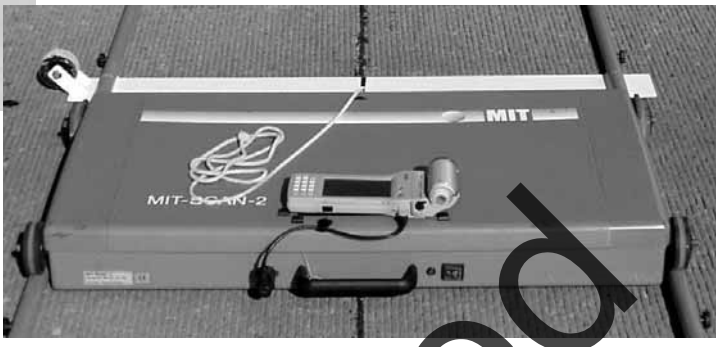
Since 1999, the Federal Highway Administration's (FHWA) Concrete Pavement Technology Program (CPTP) has conducted research on improved methods of using concrete pavement in the construction, reconstruction, and repair of Federal-aid highways. More than 30 research projects centering around the following six focus areas have been initiated under CPTP: advanced pavement design, improved concrete materials, improved construction processes, repair and rehabilitation, workforce training, and enhanced user satisfaction. Products resulting from this research that are now available or soon to be released include software, concrete materials guidelines, and construction management tools.

The Total Environmental Management for Paving (TEMP) software system, for example, can be used to monitor temperatures in newly placed pavements to determine the appropriate times to open the pavement to traffic. TEMP combines temperature, maturity, and strength predictions into a single measurement system that can be accessed on a project site or remotely with a handheld or laptop computer, providing instant feedback on pavement temperature and concrete strength development. "The strength prediction system is mature and implementable now for pavement applications," says Shiraz Tayabji of Construction Technology Laboratories, Inc. (CTL), which has been overseeing CPTP product implementation for FHWA. The software is expected to be released in 2005.

The new concrete materials guidelines resulting from the CPTP cover rapid repair and rehabilitation techniques. One example is a set of techniques for using precast concrete pavement to perform full-depth repairs of existing concrete pavements and to rehabilitate or reconstruct existing pavements. The goal is to minimize user delays by reducing the time needed for project repairs or rehabilitation, while ensuring a quality product. The full-depth precast repair technique has been demonstrated in several States to date, including Colorado, Michigan, and Virginia. The precast pavement system developed for use in rehabilitation or reconstruction incorporates prestressed panels and has been demonstrated in Texas and California. Several other States, including Indiana and Missouri, are looking at holding demonstration projects for precast paving.

Construction management tools researched under CPTP include a variety of products, from procedures to actual hardware. One promising piece of technology recently reviewed is known as MIT Scan-2. This new device is based on principles of magnetic pulse induction. The CPTP research project tested its usefulness in evaluating dowel bar placement in concrete pavements and found it to be reliable, efficient, and accurate. The device rides on tracks as it is pulled across fresh or hardened concrete and can be used to determine the position and orientation (vertical and horizontal alignment) of all dowels in a joint in a single pass. Preliminary results are available almost immediately. Developed in Germany, the scanner's algorithms and user interface have been adapted for U.S. conditions. The device is available commercially and is already in use in Europe.

CPTP has also developed 2-day workshops on high-performance, long-life concrete pavements. Workshops available are:



The MIT Scan-2 can be used to evaluate dowel bar placement in concrete pavements. The device rides on tracks as it is pulled across fresh or hardened concrete.

- Long-Life Portland Cement Concrete Pavement Design and Construction Features and Cost-Benefit Analysis of These Features
- Concrete Paving Materials and Optimization of Concrete Mix Design
- Best Practices for Concrete Pavement Design, Materials, Construction, and Rehabilitation.

Each workshop incorporates innovative concrete pavement technologies and research findings that have resulted from CPTP projects. To schedule a workshop in your State or region, or to have a condensed version of the workshop presented in conjunction with a conference or meeting, contact Sam Tyson at FHWA, 202-366-1326 (email: sam.tyson@fhwa.dot.gov).

CPTP's current technology transfer effort is scheduled to run through 2005. FHWA is developing a long-term plan to continue existing research and expand the program, with funding potentially coming from a consortium of Federal, State, and industry sources.

Reprinted from *Focus,* December 2004.

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Publication No. FHWA-IF-07-012