In addition to tenure and promotion, the teacher/researcher has an opportunity to solve "real-life" problems and interest practicing engineers by presenting state-of-the-art solutions. The individual will thus develop a technology base; management skills; and state, regional, national, and international recognition for himself or herself as well as the university.

Salaries for the professor/researcher are often below those of engineers in practice. Salary structures for professors involved in research and the basis of salary reward systems vary widely. Consulting can become a major source of income for the professor with regional or national recognition.

The reward system for the practitioner is not clear. New ideas in the form of solutions, techniques, and so forth, must be encouraged. Why should one take the risk if failures are remembered while successes go relatively unnoticed? A recognized reward system must be developed for the practicing engineer and contractor.

### Research Implementation

Implementation of research requires transfer of knowledge, which implies a giver and a receiver, and requires a cooperative atmosphere. Communication and interpersonal skills may be as important as technical information.

University teacher/researchers have played an important role in the implementation of mechanistic overlay design methods, new paving materials, new test methods, quality control, and pavement-recycling operations. Successful implementation programs have involved the Federal Highway Administration, state departments of transportation, local government agencies, and universities.

### Summary

Implementation is the responsibility of the researcher and the funding agencies. The mission of Land Grant Universities clearly involves teaching, research, and continuing education. Thus the teacher/researcher should be included in implementation. With proper organization, philosophy of higher education, and facilities, it is clear that universities are in the best position to implement research and thus "pave the gap."

## Implementation of Pavement Research Findings

ROGER L. YARBROUGH

My experience with and practical knowledge of the hot-mix asphalt industry have led me to believe that 80 percent of today's problems with the design, construction, and maintenance of hot-mix asphalt pavements could be corrected if we would only do what we already know how to do, but for various reasons are not doing. We do not need more research and new technology to improve the quality of pavements. What we do need is a better way to implement the knowledge we already have. In my opinion, the greatest challenge for new pavement research today is to use the technology that is currently available more effectively in the design and construction of higher-quality hot-mix pavements. Most of the leaders of the hot-mix industry share this view.

*Roger L. Yarbrough, president of the University Asphalt Co., Inc., Urbana, Illinois.*

### Current Research Activity and Applications

Federal Highway Administration (FHWA) officials have been stepping up efforts to implement research, showing increased concern for quality problems in all

phases of highway work. Highway leaders, who prepared the Transportation Research Board's report *Special Report 202: America's Highways: Accelerating the Search for Innovation,* which led to the Strategic Highway Research Program (SHRP), have been frustrated at the present inability of the hot-mix industry to solve quality problems with current methodology. They have come to believe that the best solution to asphalt problems is to find an asphalt cement that performs better or an additive to asphalt cement that will make hot-mix asphalt less sensitive to variations in mixing and handling, thus providing more dependable performance. The National Asphalt Pavement Association (NAPA) recently established the National Center for Asphalt Technology (NCAT) at Auburn University in Alabama, a research center primarily concerned with solving hot-mix asphalt problems by developing and applying research technology directly to the conventional hot mix as placed.

***"The greatest challenge for new pavement research today is to use the technology that is currently available more effectively in the design and construction of higher-quality hot-mix pavements."***

In addition, many meetings involving industry have been held to discuss hot-mix asphalt problems in an attempt to generate solutions. In August 1986 I was one of a group of 11 representatives of the hot-mix industry from NAPA who met with TRB committee members in Washington, D.C. The problem of bridging the gap between research and field application was discussed. The conclusions reached at this meeting that are relevant to the issues being discussed here are quoted as follows:

- "First of all, we do not now effectively apply knowledge available to us from research and we do not now effectively apply knowledge developed from past experience.
- "The technical capabilities of industry personnel are declining in both contractor and specifying agencies and in university research organizations.
- "The asphalt pavement industry is highly fragmented and lacks incentives to do quality work; technical improvement is difficult in such an environment.
- "The extent to which materials, equipment, and processes are specified by specifying agencies today inhibits innovation by contractors.
- "There are few or no rewards for better performance by personnel in the contractor or the specifying organizations; we really see only penalties for failure to meet the specs.
- "Resources available for education, training, and development of training aids continue to be limited."

### The Search for Solutions

Why don't we solve some of these problems? The issues are simple; why don't we do something about them?

I said earlier that 80 percent of the problems with the performance of hot-mix pavements could be solved if we would only do what we already know how to do. I am convinced that the underlying problem of technology transfer and use is lack of motivation. The participants in academic research and development, specifying agencies, or contractors as practitioners of the art of constructing pavements are not properly motivated to introduce and use innovative research to design and build better-performing highways. Motivation is what makes things work.

Let's look at academic research. Where is the incentive to take the papers presented at this conference and put the research to use for the end product? Where is the incentive for the researcher to follow through on this research to see that it is presented to the user in a form to be practically applied to the end product? I don't see any rewards for doing so; the rewards come from writing a paper, getting it published, meeting with your peers, receiving recognition, and gaining credibility.

*The Specifying Agencies*

Let's look at the specifying agencies—the governmental agencies that are specifying and building these pavements. What is their incentive to implement new knowledge and new research? Most research is not field tested when presented, and much is difficult for some of us to understand. What is the incentive for agency design and material engineers to dig into the research papers presented here to look for practical applications of research findings that haven't been field tested? What incentive is there for the specifying agencies to reach out and use this kind of research? I submit that most of the employees who work for governmental agencies specifying hot-mix asphalt pavements don't want to get burned by using a new procedure that may not yet be perfected. The more new ideas tried, the more exposure to the possibility of failure and criticism because something unproven was attempted. On the other hand, there are few rewards for trying something new that works. It has been my experience that specifying agencies try new things when severe problems make them desperate for answers and their present methods of operation do not provide solutions.

*The Contractor*

Let us not forget the contractor, who is mostly working under method specifications. The product is being designed, the specifications are being written, the type of equipment is being specified, and the types of materials are being specified. The method of mixing, the method of hauling, and the method of laying are all being specified by others. What incentive does he have to use new ideas? The specifications are so restrictively detailed that he has limited flexibility in making decisions to change or alter anything in the process of building hot-mix pavements. So the contractor follows the cookbook recipe required to obtain 100 percent payment. The goal of a great number of contractors is to lay as much hot-mix asphalt as possible, to meet the specifications set forth in the contract over which they have almost no control, and to get paid for their work. Whether or not they build a good pavement becomes a secondary issue. Their real responsibility is not to build a good pavement but to live up to the letter of the contract. Consequently, contractors have little incentive to be innovative in improving quality. The specifications permit so little flexibility in making changes for improvement and so little responsibility for the quality of the end product that contractors reach the point where they don't care much.

I suppose that what I have done here is to indict the whole industry or the institutional structure of the industry for simply not getting the job done. If we are going to make changes that effectively incorporate knowledge, training, and product development improvements in the hot-mix asphalt industry, some institutional changes must be made to create incentives and rewards that vastly improve motivation. Although I am not an expert on academic research or governmental agencies, I know something about the contracting end of the business.

***"If we are going to make changes that effectively incorporate knowledge, training, and product development improvements in the hot-mix asphalt industry, some institutional changes must be made to create incentives and rewards that vastly improve motivation."***

**Improving Contract Practices**

Let me suggest some ways to improve the contracting performance of our industry. One innovation would be to let contractors design and build highways contracted on the basis of producing a certain performance level for a specific highway. The expected performance level should be specified, such as the traffic volume and service level required over a period of time, with the contractor making the decisions on materials and methods. The contractor could be required to maintain a serviceability level for a certain length of time to meet the conditions of the

contract. Contracts like this would completely change the motivational factors involved in designing and building highways. Let the contractor decide whether he wants to build a safety factor into the design on initial construction or whether he wants to spend the money on maintenance later on.

This kind of contract will produce contractor innovation, dedication to quality, and cost-effectiveness because these contracts incorporate producer responsibility for performance with powerful economic incentives.

At this time we do not seem to be at the point where we can let these types of contracts in this country, but they are being let in other countries such as Sweden. However, there are some things that we are doing that do change the motivational forces at work. Specifically, quality assurance or end-result specifications, which have been initiated by many states, place the responsibility on the contractor for putting quality into the work. Contractors operating under quality-assurance specifications quickly come to grips with the fact that they are responsible for the product, the process, and the materials and have complete flexibility in putting these elements together so that a set of end-result specifications will be met.

*"Quality assurance or end-result specifications, which have been initiated by many states, place the responsibility on the contractor for putting quality into the work."*

This procedure does allow for innovation and provides great incentive and reward to the contractor who does a good job. Thus my recommendation for implementing research and building higher-quality pavements is to make the institutional changes necessary to motivate the participants to do quality work. Quality-assurance specifications are the best way we have now to transfer the responsibility for putting quality into the finished product to the contractor, who should have control over the materials, equipment, and process and should make all the decisions governing that process.

**Effective Implementation**

There are various types of tests for dynamic or stiffness moduli, flexure fatigue, creep, direct tension, and so forth, that are readily available and can be classified as rational and fundamental tests. However, because of their complexity, the use of these tests is limited to research; they are not applied to routine mix design and construction. What is needed is development of a more meaningful and performance-related test of paving mixtures over a wide temperature range. To date, research has failed to provide better performance-related tests and design procedures that are simple and straightforward; that can be directly related to pavement performance in place; and that will therefore prove more useful in the design and construction of quality pavements. Several research projects are currently being conducted—one in the Strategic Highway Research Program (SHRP) under Contract A003 and one in the National Cooperative Highway Research Program, [NCHRP Project 9-6(2)]—in an attempt to solve these problems. In this particular area, past research has failed to deal with the practical aspects of linking basic material properties and tests with pavement performance to help practitioners improve the design and building of quality pavements.