

INNOVATIONS IN HIGHWAY CONSTRUCTION: TWELFTH PEURIFOY LECTURE, 1997^a

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ABSTRACT: This paper is a summary of the remarks made by the writer for the 1997 ASCE Peurifoy Construction Research Award Lecture, October 6, 1997, Minneapolis, Minn. The paper discusses the traditional highway construction process and construction-related research done prior to 1990. The many catalysts for changes in the highway construction industry in recent years and the research related to these changes are then discussed. Future challenges in the highway construction industry and opportunities for construction-related research for construction engineering faculty are covered in the remainder of the paper.

INTRODUCTION

It is a great honor to receive the 1997 ASCE Peurifoy Construction Research Award and to give this lecture. It was a privilege to have known Professor Peurifoy and to visit with him several times while teaching at Texas A&M. It was through his efforts, and colleagues such as my early mentor at Purdue, Frank Stubbs, that the American Society of Engineering Education initiated the Construction Engineering Committee in the 1950s. This was the beginning of construction engineering as a formal discipline of engineering education. Other leaders in our educational discipline carried on these initial efforts and helped to firmly establish our profession. Many are prior winners of this coveted award.

For my address I would like to discuss the many innovations that have occurred in recent years in highway construction and the research related to these innovations. This has been prepared for a summary presentation and is not written as an academic paper since many fine publications are available on the topics I have covered. The Federal Highway Administration (FHWA) reports that 1996 expenditures were \$46.6 billion for highway construction and \$26.7 billion for highway maintenance and traffic projects. Research funding for transportation construction has been increasing for several years, mostly supported by government agencies. 1996 expenditures for highway research from the following agencies were: FHWA, \$222 million; departments of transportation (DOTs) \$164 million; and National Cooperative Highway Research Program (NCHRP), \$15 million. Obviously, this is a significant amount of funding and offers many opportunities for construction-related research to construction engineering educators.

TRADITIONAL HIGHWAY CONSTRUCTION

Highway construction is perhaps the most conservative segment of the construction industry. Although many new technologies have been implemented by highway contractors on their projects, until recently the contracting methods used by owners, typically DOTs, have been the same for many years. The traditional process for performing highway construction projects has been characterized by the design-bid-build approach. Except for emergency situations or other special circumstances, all projects were completely designed first by the owner or a consulting firm. The projects were then advertised for bidding, with all bids physically submitted as sealed bids

due by strictly enforced deadlines. Projects were awarded to the qualified bidder with the lowest total price and pay items established on a unit price basis. The specifications for highway projects were strict methods specifications and the role of the owner or agent was to inspect, inspect, inspect!!

The industry developed into a highly litigious environment of owners, contractors, lawyers, and claims consultants. In the 1980s as the Total Quality Management movement grew in the United States spurred on by major owners, transportation agencies started to question whether these traditional contracting methods were really cost effective and quality oriented. As a result many highway construction-related research projects were initiated.

CONSTRUCTION-RELATED RESEARCH PRIOR TO 1990

Beneficial research related to highway construction has been conducted for many years by agencies, universities, and consultants. Almost all of this research has been funded by state and federal agencies in an attempt to improve the quality of our nation's highways, which have become a major factor in the quality of life of our citizens. Some of the major types of projects conducted are listed below, several of which the writer has had personal experience with. A discussion of the research findings has not been included for the sake of brevity and because the topics are well known, with many research reports and publications available on the topics. Some of the major types of studies were:

1. Methods of construction
 - Earthwork, asphalt, concrete, aggregates
 - Recycling pavements
 - Equipment/plant operations
 - Work zone safety
2. Quality control/quality assurance
 - Earthwork, asphalt, concrete, aggregates
3. Maintenance/reconstruction procedures
 - Nighttime construction
 - Traffic control/phasing
4. Construction contract administration
 - Construction disputes and claims
 - Contract time determination
 - Manpower planning
 - Bonds and insurance
 - Prequalification of Bidders
 - Contract incentives and disincentives

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CATALYSTS FOR CHANGE IN HIGHWAY CONTRACTING

Starting in the mid-1980s there were several initiatives that have caused significant changes in the highway contracting business. A major factor was the willingness of the FHWA to allow highway departments to try innovative contracting ideas on federally funded projects, which encouraged the departments to consider practices long used in the private sector. A second major factor was the influence of innovative practices in highway contracting in Europe, which had been adopted while producing roadways of much higher quality than those in the United States. Several industry studies were made of European practices and the findings created high interest for possible adoption in the United States. Some of the major initiatives leading to the search for innovation are discussed in this section of the paper.

- FHWA Special Experimental Project Number 14 (SEP 14). In 1987, the Transportation Research Board, with FHWA cooperation, initiated a task-force effort to identify innovative contracting practices. The task force recommended establishing a special experimental project to evaluate its recommendations. The FHWA subsequently approved Special Experimental Project No. 14 to evaluate innovative contracting proposals suggested by the task force or those that states may propose. Many experimental contracting practices have since been approved under SEP 14 on federal-aid highway projects. A broad spectrum of innovative practices have been allowed, such as design-build, cost plus time bidding, construction warranties, lane rental, quality-based prequalification, and constructibility reviews. The results of these projects have led to several new practices now being allowed for public transportation projects.
- 1990 European Asphalt Study Tour (EAST). In 1990, a team of asphalt concrete pavement specialists from the United States visited six European countries in an effort to study advances in highway technology in those nations. The six countries visited were Sweden, Denmark, Germany, Italy, France, and the United Kingdom. The team went to observe innovations in design, materials, construction methods, equipment, and contracting procedures. The study team received the impression that the asphalt concrete pavements in these countries were in excellent condition, even under higher stress conditions than U.S. pavements. Several observations were made as to the differences in design and construction practices followed in Europe, such as long-term warranties, and the differences in the business climate. The team's final report stirred much interest in the United States for change in the highway industry.
- 1991 TRB Report on Innovative Contracting Practices. In 1987 the Transportation Research Board established the Task Force on Innovative Contracting Practices (A2T51) to identify promising innovative contracting practices for further evaluation. The goal of the task force was to identify ways to reduce the life-cycle costs in highway construction and improve the quality of highways while providing appropriate attention to contractor profitability. The task force examined (1) the effect of current contracting practices and requirements; (2) the experiences related to material specifications and newer techniques such as performance- and incentive-based specifications; (3) the potential of quality assurance (QA) efforts; and (4) the administrative, legal, and other issues that might arise in conjunction with any alternative procurement procedures. The task force made many recommendations in its final report for possible innovations on highway projects.

- 1992 European Concrete Highways Tour. A U.S. group of transportation agency and concrete construction industry representatives conducted a tour in 1992 similar to that of the 1990 EAST group. They observed portland cement highways; met with experts in France, Austria, Germany, the Netherlands, and Belgium; and talked with experts from Italy, Portugal, Spain, and Switzerland. A joint statement of the tour members was released by the American Association of State Highway and Transportation Officials in June of 1992 and offered several findings (many similar to those of the asphalt tour) related to European practices. In summary, concrete pavement systems in Europe are excellent and built for heavy loads and long life.
- 1992 National Quality Initiative (NQI). On November 10, 1992, at a meeting at the Dallas/Fort Worth Airport, eight leading organizations in the highway industry signed a pact for a National Policy on the Quality of Highways. Since then they have all participated in a partnership to provide quality products, information, and service to the highway industry. Most states now have local NQI commitments and meet at least annually to continue the commitment for improved quality in highways. The supporting organizations to this effort are: American Association of State and Transportation Officials, FHWA, American Road and Transportation Builders Association, Associated General Contractors of America, American Concrete Pavement Association, National Asphalt Pavement Association, American Consulting Engineers Council, and National Ready Mixed Concrete Association.
- 1993 FHWA European Contract Administrative Techniques for Quality Enhancement Study Tour. CATQUEST was conducted in the fall of 1993 to attempt to link innovative contract administration practices to the high levels of highway quality in Europe. If identified, the tour was to determine if such innovative practices had potential for application to the highway program in the United States. The team visited Germany, France, Austria, and Spain, where visits with transportation industry participants and inspection trips of active construction projects were made. Key areas that resulted in high-quality roadways included contractor and owner commitments to quality and testing, excellent preventive maintenance, use of staged construction with a strong pavement base, use of life-cycle cost goals, and a sound level of highway investment. The four main emphasis areas of the CATQUEST were project development and design; contract award procedures; construction quality control; and quality assessment and performance evaluation.

CONSTRUCTION-RELATED RESEARCH SINCE 1990

As a result of the many initiatives occurring in the highway industry since 1990, many research projects have been, and continue to be, undertaken on possible innovations in the highway contracting process. Many of the concepts studied are now being implemented in the industry with great interest of their success. These studies have been the topics of discussion at many national meetings of highway-related organizations such as the Transportation Research Board, the American Association of State Highway and Transportation Officials, ASCE, the Associated General Contractors of America, the American Road and Transportation Builders Association, and many others. Only a few of these studies which the writer has been personally involved with are mentioned in the paper. Many others such as performance-related specifications, time plus cost bidding, electronic control systems, and lane rental can be found in the technical publications related to the highway industry. Many other projects on innovative contracting methods are currently under way.

- Use of warranties. Highway construction projects usually require a performance bond that covers materials and workmanship on a project for up to one year after project acceptance. This is a guaranty, or warranty, for one year on the project. After the visits to Europe, their practice of requiring long-term, usually five-year, warranties has become the center of attention and controversy. Surety companies were reluctant to guarantee work for long periods of time except for very sound contractors, while many contractor organizations were opposed to warranties. Several studies have been done, and several continue, as more highway departments are requiring long-term warranties on projects.
- Constructability reviews. For years the traditional highway development process of plan-design-bid-build did not encourage construction expertise input during the planning and design phases. However, in the private sector, such input was often sought with good success. In recent years this practice has been studied often and experimented with by several highway agencies. This input is now referred to as constructability review and is becoming standard practice in many agencies.
- Alternative dispute resolution. During the 1970s and 1980s in highway construction, the practice of construction claims management became a major concern of agencies and contractors, with both sides trying to gain the winning advantage. Lawyers flourished in this environment and many research projects were undertaken to seek solutions to this situation; many continue to be done. The practice of seeking to avoid formal claims on highway projects has become known as alternative dispute resolution; several techniques are being used, such as mediation and dispute review boards. Partnering was implemented on construction projects to help avoid conflicts through better working relationships between all parties on projects. This continues to be a research area of high interest in the transportation industry.
- Preselected bidders. For many years owners in the private sector have used preferred groups of bidders for their projects by selecting only firms that meet established criteria and limiting the number who can bid on their projects. The firms selected usually try very hard to do quality work to remain on the preferred list. In recent years this group was further asked to provide constructability input during design. This practice is not allowed on public agency work and all projects are open to all qualified bidders. Some research is now underway to experiment with this system for public projects. Such a project is underway for the Paris Pike Reconstruction Project in Kentucky. The writer is conducting this research for the Kentucky Transportation Cabinet to see if the project outcomes are better than those attained on traditionally contracted projects.
- Electronic bidding. For years the traditional process for submitting bids for highway projects has been a sealed bid in an envelope, which must be physically submitted to a highway department office prior to a deadline. Many times this was a hardship for contractors who resided in other cities as they had to worry about the travel problems in addition to last-minute bid preparation. With the advent of computer technology and the Internet, many agencies are now investigating the possibility of setting up a process for having contractors submit their bids electronically. Many now accept bids on diskette with a hard copy also required; however, no agency is truly accepting bids electronically. The writer just completed a study for the Transportation Research Board on the feasibility of electronic bidding; several issues must be resolved before it becomes standard practice in the industry.

FUTURE CHALLENGES IN HIGHWAY CONSTRUCTION

Innovations in highway contracting practices are just beginning. After years of practices suspended in time, many innovations are now being considered and adopted. It is an exciting time for the industry and for those who are researching possible innovative practices. Several of the innovative practices adopted such as warranties, A + B bidding, constructability reviews, performance specifications, and partnering are now being implemented in some states with many others considering such practices. Several other innovative practices are also under review and study for possible implementation. These include such practices as design-build, design-build-maintain, quality-based prequalification, end result specifications, contractor quality control-owner quality assurance, full electronic bidding, and others. In addition to innovative contracting practices, there will continue to be a demand for identifying enhanced technologies such as construction equipment automation, new construction materials, improved design methods, and improved construction operations. There will be much support for further study and evaluation of these innovative practices and technologies with many resulting in formal research projects conducted by DOTs, consultants, and university researchers.

FUTURE HIGHWAY CONSTRUCTION RESEARCH OPPORTUNITIES FOR CONSTRUCTION ENGINEERING FACULTY

It is truly an exciting time to be involved in the highway construction industry in the United States. The current innovative environment offers many opportunities and challenges to transportation agencies, design firms, contractors, suppliers, and researchers to work together to identify and implement beneficial new ideas into practice. This will provide many opportunities for construction engineering faculty to obtain funding for research projects. However, faculty will have to develop the expertise needed to conduct the research, will have to find sources of support, and will have to do quality research if funding is obtained.

There are several sources of potential support for funding of highway construction research. Obviously, a major source of funding will be state DOTs. At the national level potential funding is available through FHWA and the Transportation Research Board, primarily through its National Cooperative Highway Research Program. In the future it may also be feasible to obtain support for research from highway contractors or their professional associations; from transportation authorities for transit, ports, harbors, and waterways; and from railroad companies.

It is essential that construction engineering faculty be informed on state-of-the-art practices for highway construction if they want to be competitive for highway research funds. The first source of such knowledge is interaction with local and state highway departments. They should also interact with their local highway contracting associations and contractors. At the national level excellent information on state-of-the-art practices is available through meetings of the Transportation Research Board, ASCE, the American Association of State Highway and Transportation Officials, and national contractor associations. Several of these organizations also have professional and technical committees that faculty members can participate with. Faculty will have to earn the right to participate and must do a good job when selected for interaction or to conduct research projects. There will be a lot of competition, and only those providing quality service will succeed.

RECOMMENDATIONS TO CONSTRUCTION ENGINEERING FACULTY

Construction engineering faculty interested in pursuing highway construction-related research should consider the following recommended activities:

- Get involved with local and state DOTs. Find out what their needs are for possible construction-related research and let them know what you can do. If you have a transportation research center in your university, then work through your center to offer your expertise and service for research. If you have an opportunity to do research, then do a good job.
- Get involved with the Transportation Research Board, especially its Construction Section, which has nine committees working on construction-related topics. The only way for you to get involved is to attend the annual meeting held in Washington D.C., each January and attend committee meetings and sessions. With continued involvement, opportunities for committee membership will occur. For more information on the Transportation Research Board, look them up on the internet at <http://www.nas.edu/trb/>.
- There are many opportunities at present to research contracting practices for highway construction. However, construction faculty should also develop expertise and pursue research on technical topics such as asphalt, concrete, quality control, and earthwork. This will greatly enhance the potential for obtaining transportation research support. A good way to pursue such support is to work with faculty with technical expertise in other areas of transportation and seek their help.
- Use applied research projects to stretch the envelope of knowledge for transportation. Many faculty are concerned that the research funding for many transportation projects is for applied research. They are afraid that such research will not be publishable in technical journals. If one has funding to support graduate students for applied research, it is simply a matter of having your students perform the research for the sponsor, do research at the same time for their degree that will contribute to the knowledge base, and publish such findings. Often the applied research will result in publishable results. In other words, faculty need to be innovative about using existing funding to support their research.

CLOSING REMARKS

I am deeply honored to receive the 1997 ASCE Pourifoy Award for Construction Research. It is especially meaningful coming from a group of my peers. Obviously, no one has a successful career without the help of others, and I have been blessed with many outstanding mentors and supporters throughout my career. I have been very fortunate to receive support from the Joint Highway Research Project at Purdue, the Texas Transportation Institute at Texas A&M, and the Kentucky Transportation Center at Kentucky. I have had tremendous activities with the Transportation Research Board and

other technical organizations. I would like to recognize some of the key persons who have assisted me in my career.

John Havers was my major professor and later my mentor at Purdue University; his dedication and demands for excellence were invaluable in my early career development. Richard Tucker was instrumental in my appointment at Texas A&M and in my involvement in the Construction Industry Institute, where I had many excellent research experiences. Harold Michael was instrumental in supporting my research interests in highway construction in Purdue's Joint Highway Research Project in my early years as an academic. Many others have contributed to my career achievements, too many to mention for fear of omission, and I thank them also.

I would also like to thank the many outstanding students who have worked with me over the years at Purdue, Texas A&M, and Kentucky. It is an exciting and gratifying experience to work with bright and dedicated young persons and play a small role in their professional development. I am proud of the achievements of my many former students and would like to thank them for their contributions to my research efforts these past many years. My recognition for this prestigious award was largely due to their efforts.

I am proud to be a civil engineer and a construction engineering educator. We have accomplished much in the past 25 years to maintain engineering as a viable path for preparing bright young civil engineers for careers in the construction industry. We have also made many contributions to the industry through our research and professional development activities. I truly believe that we have made a difference and that the many young persons entering our profession will contribute even more in the future. The outlook for construction engineering education and research is good, and I hope to continue to participate in these endeavors for several more years. Thank you to all who played a part in my receiving this award from ASCE.

APPENDIX. BIBLIOGRAPHY

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