Iowa Highway Research Board: 1949–1999

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Joseph M. Isenberg

TR-423

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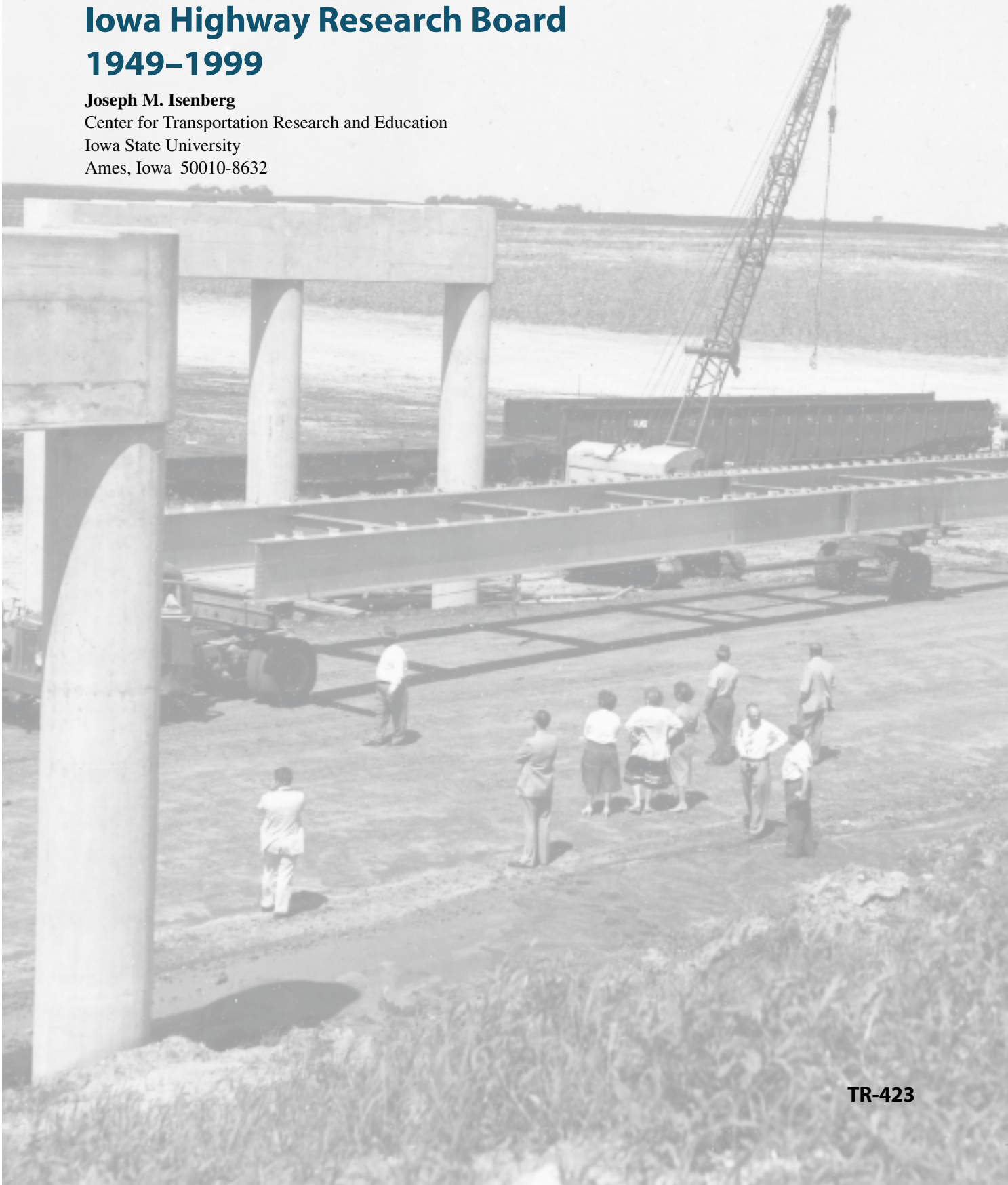

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Cover and title page photos
The Northwest 86th Street overpass on Interstate 35/80 in Urbandale, Iowa, shown here under construction in 1958, was the country's first aluminum girder type highway bridge.

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At Iowa State University, Professor of History R. Douglas Hurt carefully read this manuscript and made many good suggestions. Kenneth G. Madison, also of the Iowa State University History Department, read the manuscript as well and made many helpful suggestions.

Introduction

The year 1949 saw the Iowa General Assembly's establish-ment of the Iowa Secondary Road Research Fund, which led to the creation of a supervisory board within what was then the Iowa State Highway Commission to oversee the expenditure of that fund. The purpose of the fund and the board was to research road construction topics likely to be beneficial to the working of Iowa's secondary, or local, road system. The supervisory board—called the Iowa Highway Research Board (the "Board")—was organized by the highway commission in December 1949 and first met in May 1950.

The creation of the fund and of the Iowa Highway Research Board marked the first organized effort in the United States to investigate local road construction problems and placed Iowa in the forefront of this field of engineering research. That Iowa should be a leader in such an effort is not surprising, given the early and sustained emphasis of the Iowa State Highway Commission on both research and the dissemination of information to county authorities.

Now, 50 years later, a retrospective is in order. To that end, the Iowa Highway Research Board commissioned the preparation of a commemorative history. This work is the result of that project. Throughout its existence, the Board has funded nearly 450 projects, several of national significance. Many new construction and maintenance techniques have been developed, some of which have evolved into standard practices in highway construction. Innovative new materials and equipment have been tested. Still other projects have considered a wide variety of subjects related to the efficient operation of the highway system. Highway safety, conservation, and law have all come under research scrutiny.

While it will not be possible, given the short space available, to consider all the projects financed by the Iowa Highway Research Board, it is well worthwhile to examine the Board's principal projects and its resulting contributions to the field of highway research.

Early Efforts at Highway Research in Iowa

In 1949 the Fifty-Third Iowa General Assembly passed legislation creating the Secondary Road Research Fund to be administered by the Iowa State Highway Commission in consultation with the state's county engineers. The fund was to be expended in pursuit of solutions to engineering problems in the construction and maintenance of Iowa's secondary roads. To administer this fund and to guide the research contemplated as a consequence, the Iowa Highway Research Board was created within the highway commission.

By creating the Secondary Road Research Fund and the Iowa Highway Research Board, the state of Iowa placed itself in the forefront of highway research in the United States. Although the federal government had engaged in highway research since 1893, results had been decidedly mixed. State highway authorities, including the Iowa State Highway Commission, had also conducted ad hoc research in problems of interest. By 1949, however, no sustained program or central management for research had emerged in any of the states. Thus, the creation of the Secondary Road Research Fund and the Iowa Highway Research Board marked a new departure for engineering research. By its actions, Iowa was the first state to create a central agency to manage a highway research program. Other states soon followed this model.

For the next half century, the Iowa Highway Research Board would undertake a wide variety of research projects deemed useful to the practice of county, municipal, and state road builders. Several of those projects would receive national and international recognition for the novelty and utility of the results. What follows is the story of the Iowa Highway Research Board.

Iowa's first "road schools"

It is scarcely surprising that Iowa placed a heavy emphasis on highway research. In the early 1900s the first chair of the Iowa State Highway Commission, Anson Marston, was an early advocate of engineering based on the scientific method. Marston represented a trend toward increasing professionalism in the engineering field whereby experimentally derived information increasingly replaced traditional rule-of-thumb approaches practiced early in the twentieth century without regard for empirically testable theories. As an example of this trend towards scientific information in engineering, some of Marston's research at what was then Iowa State College focused on providing experimentally designed charts for road builders.

Anson Marston
Marston was professor and dean of engineering at Iowa State College. Together with Iowa State's Charles F. Curtiss, he served on the Iowa State Highway Commission. In his work at both the college and the highway commission, Marston stressed the importance of research in engineering work. In the first year of the highway commission's operation, Marston sponsored a road building course to familiarize county officials with construction techniques.

1905 highway commission road school
In this scene, participants are shown building a "modern" concrete culvert. Practical experience allowed local officials to gain valuable insights with materials and techniques then not often used in local road construction, such as concrete.

The finished product
While the concrete culvert may look primitive by modern standards, it was clearly a considerable improvement over wooden culverts commonly used at the end of the nineteenth century (below). By making plans for concrete culvert construction available to officials upon request, the highway commission was able to reach far more individuals than could be reached through the operation of the road

Given his background, it is not surprising that Marston wished to engage the Iowa State Highway Commission in a research program. Faced with a lack of trained personnel at the state and county levels and a lack of information about modern road construction, Marston sought to develop all aspects of road engineering. Thus, in the First Annual Report of the Iowa State Highway Commission, covering the 1904–1905 fiscal year, Marston and Charles F. Curtiss, in requesting additional funds for the highway commission, wrote:

> We need funds to carry on extensive laboratory tests of the properties of Iowa road materials, and to build sections of experimental roads, to give actual working tests of material and methods of construction suited to Iowa's needs.
>
> We need funds to determine by actual tests the dimensions of concrete culverts and bridges necessary for strength to prepare full plans and specifications, and to employ an experienced concrete foreman to give actual demonstrations.
>
> We need funds to complete the compilation of the road census and publish the results.
>
> We need funds to extend our county investigations, and to complete our road maps.

Marston and Curtiss concluded their plea by requesting an increase in the highway commission's budget to the minimum necessary to carry out the proposed program, which they estimated at $10,000 per annum. Without these additional funds, Marston and Curtiss argued, the "future work" of the highway commission would "be very seriously crippled."

In addition to the lack of highway commission funds, road building in Iowa was then handicapped by a lack of trained individuals able to manage county and city road construction. Marston and Curtiss proposed to rectify this lack of expertise in two ways. They first undertook the creation of a training program for local road builders. The "road school" allowed for the training of a few individuals and also allowed the refinement of construction technique. Second, once construction technique was developed, Marston and Curtiss made this information available to local officials, together with such other research as the highway commission was able to undertake.

As part of these efforts, the Iowa State Highway Commission built two sections of experimental road in the 1904–1905 fiscal year. One road section, near Ames, was built of gravel and clay. The other section, near Anamosa, was built of stone. The highway commission also undertook to build several experimental concrete culverts to demonstrate construction technique.

The road school approach proved particularly helpful in disseminating information. Participants drawn from county and city road crews were able to work with concrete on road sections and with the experimental concrete culverts. As Marston hoped, the highway commission made the culvert plans available to local road builders on request.

Through a program of research, practical education, and dissemination of standardized information, Marston sought to improve the level of expertise among county road building officials. However, despite the need for a formal research and dissemination program aimed at improving local road building expertise, and despite the apparent utility of Marston's early efforts to develop such a program, no formal research organization aimed at solving county engineering problems existed until the creation of the Iowa Highway Research Board in 1949. In the interim, the Iowa State Highway Commission focused on its own research needs. The highway commission conducted intermittent investigations and occasionally cooperated with national highway research efforts sponsored or organized by the national Highway Research Board of the National Academy of Sciences or by the U.S. Bureau of Public Roads.

Early federal research

Although not extensively developed, Iowa's early efforts at highway research compared favorably to efforts undertaken by the federal government at approximately the same time. The agency principally responsible for federal transportation research was the U.S. Bureau of Public Roads. Bruce Seely, in one of the few works on the history of highway research, evaluated federal research efforts during the first few decades of the twentieth century in an article in the October 1984 issue of *Technology and Culture*. Seely described the early federal research program as by and large a failure. He argued that in the aftermath of World War I the federal engineering research program aggressively embraced scientific methodology. Unfortunately, the change from improving engineering practices to formulating general theories of engineering based on "fundamental" principles neither solved practical problems faced by engineers in local conditions nor provided basic information on materials.

The use of the scientific experimental method marked a fundamental change in operating procedure for the organization that would eventually become the U.S. Bureau of Public Roads. The Office of Road Investigation, formed in 1893, began by collecting statistical data on roads in the United States. It soon turned to physical testing of construction materials in a materials testing laboratory built in 1900. As a

Concrete samples cure prior to testing
The highway commission also undertook basic research in materials similar to that undertaken by the U.S. Bureau of Public Roads. Here, concrete samples cure prior to testing in the early 1920s.

Concrete slabs
Practical research in pavement testing was also of interest to the highway commission. Here, concrete slabs of various thicknesses are laid out, as they would be in pavement, to be used in testing.

Load testing
A sample of concrete is loaded to determine its flexural strength.

result of this work, the office, renamed the Office of Public Roads, quickly gained a reputation for research expertise. By 1907 the Office of Public Roads was undertaking both road tests on public roads and experimental road construction at an experiment station in Arlington, Virginia. As a result of these efforts, by 1911 the Office of Public Roads was in a position to offer specifications both for road construction and testing methods. These recommendations were widely adopted by local road builders. The tests undertaken were overwhelmingly practical with no effort at synthesizing any theories of material behavior.

The work of the Office of Public Roads and the methods used by the office to arrive at specifications were called into serious question during a transportation crisis in World War I. Due to a railroad shipping backlog, the War Department decided to move trucks under their own power from the Midwest to ports on the East Coast. The roads selected for this movement were, for the most part, built to Office of Public Roads standards and were considered to be the most modern roads in the United States.

The project failed miserably. Road surfaces, incapable of taking the stress of several heavy trucks, failed completely within a few weeks or months. The finest roads in the country were thus rendered impassable. In response, in 1918 the renamed Bureau of Public Roads undertook a program to discover the "fundamental" principles of road design based on the statistical analysis of road surface failures. The bureau also sponsored extensive analysis of soil characteristics and behavior.

Unfortunately, these efforts led to little in the way of practical consequence. Although researchers were able to collect a great deal of information on the destruction of materials both in the real world and in the laboratory to which the bureau's engineers increasingly retreated, they were unable to correlate that research with any improved road design methods. Similarly, while the bureau was capable of generating significant information about soil types and the physical properties of a wide range of soil samples, it was unable to form a general theory of soils, as had been hoped, or to determine which soil conditions were relevant to road construction practices.

In contrast, state officials working with the Bureau of Public Roads were able to develop practical information quickly by constructing experimental road sections using a variety of techniques and comparing durability among techniques. This trial-and-error method was derided by federal engineers as unsophisticated and incapable of producing "scientific," verifiable results.

Highway research was impeded by the needs of the second world war. After the war, renewed interest in research led to the creation of a number of highway research organizations both in the United States and abroad. The first of these was the Iowa Highway Research Board.

Iowa's farsighted legislature

In 1949 the Fifty-Third Iowa General Assembly undertook a general revision of the highway laws of the state. Special attention was given in this revision to the workings of the secondary—or local—road system. The general assembly clearly hoped to establish the planning and construction of the secondary road network on a more professional and systematic basis.

As a result, counties were required for the first time to prepare county road plans and to have those plans approved by the Iowa State Highway Commission. The road use tax fund was created in Iowa and allocated between the primary and farm-to-market road budgets. The financing of secondary roads was carefully detailed.

As a small part of this overall legislative plan, the general assembly passed House File 54, "An act to establish a fund for financing engineering studies and research projects in connection with the construction and maintenance of secondary roads." This act, which became Chapter 128 of the session laws and which found its way into Chapter 309 of the Iowa Code, established a permanent fund for highway research in Iowa and dictated how that money was to be spent.

The general assembly, in House File 54, set aside a portion, not to exceed one and one-half percent, of the new farm-to-market road fund to be used for secondary road research. This fund was designated, not surprisingly, the "Secondary Road Research Fund."

Under the terms of the enactment, the Secondary Road Research Fund was to be used "solely for financing engineering studies and research projects which have as their objective the more efficient use of funds and materials that are available for the construction and maintenance of secondary roads." The act expressly included bridges and culverts on secondary roads as fit objects for research scrutiny.

Management of both the Secondary Road Research Fund and the actual research envisioned was confided to the Iowa State Highway Commission. The highway commission was to undertake this task in cooperation with the state's county engineers, although the exact mechanism for this cooperative management was left undefined. The general assembly provided that an annual report of research undertaken or accomplished would be made by the highway commission to the governor and the county engineers and that a biennial version of this report would be laid before both houses of the general assembly in odd-numbered years. All other details were left to the discretion of the highway commission. The highway commission authorized uncommitted primary funds for primary road research. This allotment, designated the "Primary Road Research Fund," is authorized annually.

Concrete pipes subjected to stress testing in the early 1920s

With a structure for research funding now in place, the Iowa State Highway Commission could begin to organize the research of interest to both highway commission and county engineers. The highway commission wasted little time and promptly proceeded with the work at hand. The organization created as a result, the Iowa Highway Research Board, began work in May 1950.

Germination of the Iowa Highway Research Board

To manage the Secondary Road Research Fund and the research envisioned by the Iowa General Assembly, the Iowa State Highway Commission created the Iowa Highway Research Board in December 1949. The Board originally consisted of 11 members serving three-year terms.

Six members were nominated by the president of the Iowa County Engineers Association from among the county engineers of the state. These appointments were made by highway commission districts to ensure that the Board would be geographically balanced and funds equitably apportioned. Three appointments were made by the Iowa State Highway Commission from among the engineering personnel of the highway commission, each nominated by the highway commission's chief engineer. The presidents of what were then the State University of Iowa and Iowa State College each nominated one member. As a practical matter, these nominations were usually the deans of the appropriate engineering faculty at each school or their designees. Although the county engineers association, the state universities, and the chief engineer of the highway commission were accorded the privilege of nomination, the highway commission retained the right to approve nominations. In practice, of course, none was ever rejected. This arrangement, however, allowed the members of the Board to be described as "consulting engineers" of the highway commission, a designation necessary for the payment of expense money. At the board's June 1950 meeting, alternate members were appointed by the same process to serve in the absence of regular members.

Early leadership

By May 1950 the first nominations to the Iowa Highway Research Board had been confirmed by the highway commission. The first members were R. E. Robertson, P. A. Michel, C. A. Elliott, J. R. Dougherty, Edward Winkle, and L. J. Schiltz for the county engineers association; W. E. Jones, Bert Myers, and W. H. Root for the Iowa State Highway Commission; F. M. Dawson for the State University of Iowa; and J. F. Downie Smith for Iowa State College.

Fred White
White, long-serving chief engineer of the Iowa State Highway Commission, organized the Iowa Highway Research Board and served as temporary chair during its first meeting on May 18, 1950.

The first meeting of the Iowa Highway Research Board was held on May 18, 1950. The chief engineer of the highway commission, Fred White, served as temporary chair. The Board promptly elected W. E. Jones as its chair and Bert Myers as vice-chair. Fred White then presented the director of highway research for the highway commission, Mark Morris. According to the organizational plan set up by the highway commission, Morris would serve as secretary to the Iowa Highway Research Board by virtue of his position as director of highway research. Morris held this position for 10 years until his retirement in 1960.

The Northwest 86th Street overpass under construction in 1958

Morris had once been introduced to a convention of the Iowa Good Roads Association as a "walking encyclopedia" of information related to the highway commission, highway construction, and engineering practice in general. A review of Morris's career shows that the praise was not necessarily hyperbole.

Morris was born on August 9, 1893, near Stockport, Iowa. He attended schools in Bentonsport and Keosauqua and graduated from Iowa State College in 1921 with a degree in civil engineering. Even before he completed work on his degree, he was employed by the Iowa State Highway Commission as an engineer for concrete bridge and culvert construction and for road surveys and plans, and as a materials inspector. In December 1920 Morris was appointed as the research assistant to the engineer of materials and tests. After his graduation, he continued to hold this position. In April 1936 he was appointed director of the statewide highway planning survey. In December 1938 this position was made permanent, and Morris became the director of planning and survey operations. He also assumed the title of traffic engineer at this time. In June 1950 Morris assumed the responsibility of director of highway research.

In addition to his regular duties, beginning in 1921 Morris was responsible, as special assistant to the chief engineer of the highway commission, for the preparation and presentation of proposed highway legislation to the Iowa General Assembly. In this capacity he prepared reports for the general assembly, such as one discussing the feasibility of toll roads in Iowa in August 1954. He was available for special research projects and was also responsible, along with others, for the compilation and preparation of the periodical revision of the state highway map.

Somehow Morris found time to carry on research of his own. In 1925, for example, he prepared a nationwide survey and report on the performance of highway culverts for the national Highway Research Board. These outside endeavors gained him a national reputation as an expert on concrete construction, and he continued to receive invitations to perform research from other agencies after the formation of the Iowa Highway Research Board.

In August 1954, according to the highway commission's internal newsletter, the "Employee Information Bulletin," Morris received the unsolicited offer of a position with the United Nations in Technical Assistance Administration. It was hoped that Morris would bring his considerable expertise in statistics and transportation to bear on behalf of the Republic of Colombia. The Colombians hoped to utilize his skills in the "recommendation and implementation of procedures for the completion and modernization of all statistical data relating to all methods of transportation in Colombia."

Mark Morris
Morris, the first secretary to the Iowa Highway Research Board, is shown here in March 1963 with the Distinguished Service Award of the Iowa Engineering Society. When he received the award at the society's seventy-fourth annual meeting, he was only the sixth person in the history of the society to have been so honored.

While Morris declined that offer due to the uncertainty of the tenure of the position, October of the same year brought his appointment to a National Academy of Sciences committee to study the effect of jet aircraft on runway pavements. At the same time, Morris was appointed to a National Academy of Sciences panel to advise the government of India on the creation of central research institutes being built with American funds. Morris's specific function on the panel was to give advice related to highway research facilities.

Amazingly, given his responsibilities at the Iowa State Highway Commission, his private research interests, and his national research commitments, Morris still found time to putter in his flower garden.

When the seed of the Iowa Highway Research Board first germinated in May 1950, Morris played a central role in its cultivation. He advised the Board of the existence and purpose of three research projects then being undertaken by the Iowa State Highway Commission. He served as a contact to enable Board members to compile a list of potential research projects in consultation with the county engineers in their respective districts. He provided information about available funds. He recommended research projects to the Board. Finally, he served as the liaison between the Board and the highway commission.

Selecting the first projects

When the Iowa Highway Research Board was formed, the Iowa State Highway Commission had in hand a few research projects, including an investigation of stream bed scour at bridge piers and a study of roadside seeding, that were taken over and completed under the supervision of the Board. The study of scour at bridge piers, completed as HR-30, led to significant findings cited worldwide and allowed engineers to formulate solutions capable of lengthening the useful lives of bridges.

To create awareness of the work of the Board, Morris circulated a notice of the proceedings of the first meeting. This memorandum went not only to members of the Board but also to all of Iowa's county engineers. The notice requested that suggestions for research projects be sent to Morris not later than May 31, 1950, for consideration at the next meeting on June 2. Despite the relatively short notice, 17 proposals were received and were discussed at the second meeting. These proposals were as follow:

1. Accelerated testing of highway pavement and bases.
2. Investigation of the loess and glacial till materials of Iowa.
3. Investigation of the supporting strength of concrete pipes.
4. Investigation of motor vehicle operating costs.
5. Origin and destination traffic surveys.
6. Methods for the elimination of long bridges on streams with small drainage areas.
7. Analysis of flood frequency and magnitude.
8. Determination of flood discharge for streams with small drainage areas.
9. Methods to strengthen pony trusses for heavier loading.
10. Treatments for wooden bridge floors.
11. Investigation of precast concrete bridge floor construction.
12. Determination of the necessary thickness for stabilized aggregate bases for use with bituminous surfaces.

13. Standardized accounting practices for county engineer offices.
14. The hydraulic design of highway culverts.
15. The hydraulic design of highway valley crossings.
16. Investigation of limestone in east central Iowa for low cost road construction.
17. Creation of economical methods of highway construction on earthen fills, with an emphasis on erosion resistance during flooding.

Some of these ideas were committed to special committees for consideration and taken up at another meeting on June 30. Specifically, proposal number two was handled by a committee, seven and eight by another committee, 12 and 16 by a third committee, and proposals six, 15, and 17 by a fourth committee. The remainder were ultimately handed over to Morris for analysis before being considered by the Board.

On June 30, the special committees reported. Items two, six, seven, and eight were recommended immediately as research projects for the Board. The information on aggregate bases requested in item 12 was found to be available from highway commission sources. The Board decided to have the information compiled, Bert Myers having volunteered to do it for the county engineer requesting the project, and then published for use by other county engineers. Item 15 was deferred to a later date and item 17 held for further study.

Morris also analyzed funding sources available to the Iowa Highway Research Board. He advised the Board that over the next three fiscal years he expected the following sums to be available for highway research. From federal sources, he expected $223,837, some of which was to be matched with state funds. The farm-to-market fund, Morris anticipated, would yield $540,000 during the same period, for a total of $763,837. Primary road research funds, also to be administered by the Board, might amount to another $206,000. However, Morris pointed out that funds for highway planning surveys would have to come from this research budget. In the final analysis, Morris expected $180,959 to be available each of the next three years for highway research.

As a result of this flurry of activity, the Board was able to propose six items for funding to the Iowa State Highway Commission. These were promptly approved. The first six projects were the following:

1. Investigation of loess and glacial till materials.
2. Analysis of flood frequency and magnitude.
3. Determination of flood discharge for small drainage areas.
4. The thickness of stabilized aggregate bases to use with bituminous surfacing.
5. Elimination of long bridges on streams with small drainage areas.
6. Highway embankments constructed to resist washout by overflow.

The Iowa Highway Research Board was up and running and moving fast.

Early results

During its first 10 years, the Iowa Highway Research Board undertook dozens of projects. Many of these proved to be of lasting significance. From the start, basic science, engineering, and some other matters of interest to county engineers were examined in research funded by the Board.

Among the first group of projects approved by the Board and funded by the highway commission was HR-1, an investigation of loess soil and glacial drift materials. This work, undertaken by D. T. Davidson, professor of civil engineering, and others at Iowa State College, was initially funded with $45,000 for three years. The investigation consisted of basic soil research similar to that undertaken by the Bureau of Public Roads. Ultimately, the investigation was extended for 10 years and led to significant advances in the field. As will be seen, however, while the work advanced basic science, it was not easily correlated to engineering practice or construction technique, and the difficult and voluminous research came to an end in the early 1960s.

More practical results came from other projects. Two of these projects were the development of sufficiency ratings for secondary roads and the construction of a bridge using aluminum rather than steel in an interstate overpass near Des Moines.

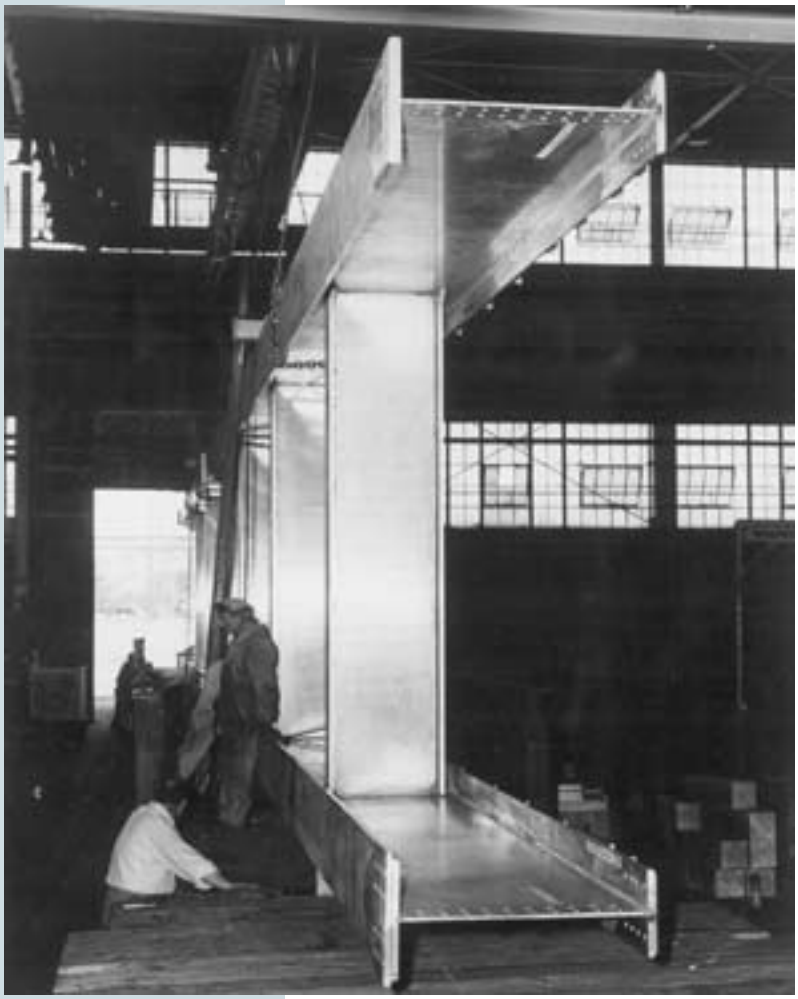
Sufficiency ratings, a systematic method of analyzing the physical characteristics of a roadway along with the area it serves, had long been used by the Iowa State Highway Commission in an attempt to allocate primary road resources on an objective, impartial basis. Despite the utility of such a system for allocating scarce funds, no such system had been developed for local use.

Then in 1956 a controversy erupted in Marion County over improvements proposed for the secondary road system. Several local citizens sought improvements to roads near them. The county board of supervisors, pointing to other roads with an equal or greater need for improvement and assigned a higher priority by the supervisors, declined the request. After some months of unresolved debate, both sides of the dispute appealed to the Iowa State Highway Commission for arbitration. The highway commission had no legal standing to resolve the matter, but both sides sought to enlist the expertise of its staff in determining the worthiness of their positions.

Lacking legal authority, and perhaps sensing political danger, the highway commission declined to judge the merits of the dispute. Instead it suggested that Marion County's board of supervisors systematize its resource allocation by devising and using sufficiency ratings similar to those employed by the highway commission. This idea seemed acceptable to the disputants. The highway commission also recommended that the board of supervisors prepare a research proposal for the project. The supervisors were thus encouraged to turn to the Iowa Highway Research Board for assistance in creating the sufficiency rating system. Upon receiving the proposal from Marion County, the Board suggested that it be broadened to allow the system to be used by any county in the state, not just Marion County. The highway commission approved this more comprehensive scheme for the research project. Development of the sufficiency ratings system continued until 1960, when a report was given by Mark Morris to the Iowa Conference of County Engineers.

This project was significant not only for its useful product but also as an example of extending state expertise to county government, without state control. Through the

rating system, county engineers and county supervisors responsible for the allocation of secondary road funds were provided with a scientific, objective method for determining the adequacy of their local road networks. Thus armed, boards of supervisors could work towards equitable allocation of funding and planning. No single county could have been expected to undertake such a project, despite its obvious political utility, yet all counties faced similar problems. The work was deemed significant enough to publish, together with exemplary charts, in May 1963 in Highway Research News, the journal of the national Highway Research Board of the National Academy of Sciences. The Iowa system of local sufficiency ratings thus received national exposure.



Aluminum subassembly
A giant aluminum subassembly for the first aluminum girder type highway bridge passes through the door at Pullman Standard Car Manufacturing Company's plant in Chicago. Each subassembly measured 12 feet wide and ranged from approximately 95 to 126 feet in length.

A project of a different sort was undertaken in 1958 with the construction of the Northwest 86th Street overpass on Interstate 35/80 in Urbandale, a suburb of Des Moines. The construction of the interstate system necessitated the reconstruction of a large number of intersecting streets, and in this instance the Iowa Highway Research Board availed itself of the opportunity for an experiment.

In January 1957 the Iowa Highway Research Board undertook research essentially requested by the highway commission for the study of the use of aluminum in bridge construction. Faced with an ongoing scarcity of conventional construction materials like steel, the highway commission wished to investigate alternatives, including aluminum. It therefore directed one of its engineers, Neil Welden, to investigate the potential for aluminum as a construction material. Welden, although acknowledging that aluminum could be used for construction, was not enthusiastic due to cost considerations.

Despite Welden's misgivings, the highway commission forged ahead and directed Welden to confer with the design department of Alcoa in Pittsburgh. The aluminum designers assured Welden that aluminum could, in fact, prove a very suitable material for bridge construction. Operating on the hope that aluminum might become economically competitive with steel through frequency of use, the highway commission began working on a research project. The Iowa Highway Research Board supervised the project and was encouraged by a research contribution of

$10,000 by each of the principal aluminum refining corporations in the United States: Alcoa, Kaiser Aluminum, and Reynolds Metal Company.

On January 25, 1957, the Iowa Highway Research Board approved the project as HR-51. The aluminum bridge project was to begin as a feasibility study. If the highway commission decided to continue with the construction of a bridge, that work would also be supervised by the Board. The Board hired Edward Ashton as a consulting engineer for the project and charged him with designing the bridge. When the work proved feasible, the Board proposed locating a prototype as an overpass on Interstate 35/80 in Urbandale.

By October 1957 Ashton had produced three sets of prototype plans: a welded arch bridge, a riveted arch bridge, and a welded girder bridge. The highway commission, less interested in aesthetics than practicality, adopted the low-cost design, the girder bridge, estimated to cost $127,000. Ashton waxed enthusiastic to Morris:

> Our design is not a straight substitution of aluminum for steel in a conventional steel beam design but rather it is the most modern welded aluminum beam and concrete floor bridge design that has ever been

Travel by rail
One of four aluminum subassemblies for the Northwest 86th Street overpass is prepared for shipment by rail. Each subassembly required three railroad cars.

The Northwest 86th Street overpass under construction in 1958
A crane lifts the aluminum girders into place.

> attempted. It is at least ten or twenty years ahead of the rest of the typical conventional steel and concrete bridges that are being built. . . . It is designed in the most advanced fashion . . . to be fabricated from the newest and best noncorrosive structural alloys by the most modern and best of all arc welding procedures.[1]

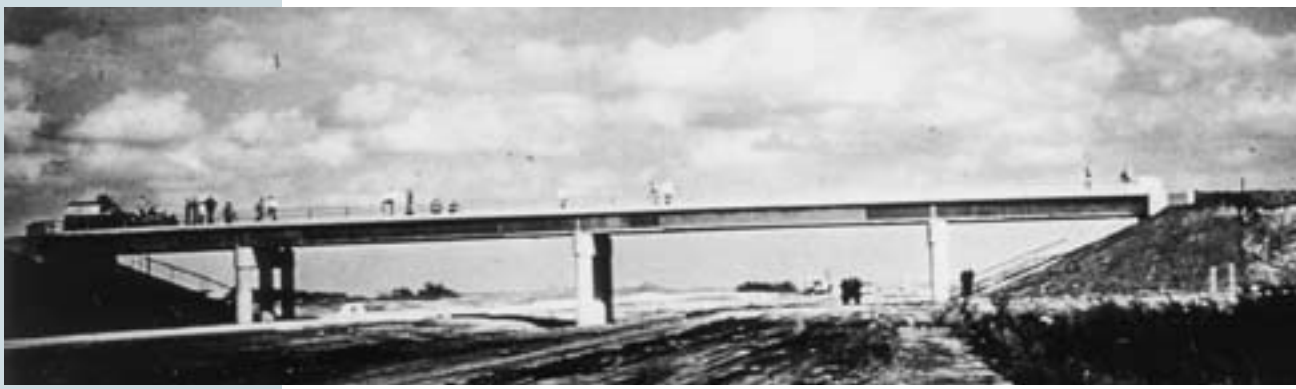
Once the Iowa State Highway Commission approved Ashton's plan, the U.S. Bureau of Public Roads fell into line and approved the plans by December 1957. The bureau indicated to Morris that interstate road funds for overpass construction would be made available to the highway commission only to the extent of the estimated cost of a similar steel or prestressed concrete structure. The highway commission, Morris advised the Board, proposed to solicit donations from aluminum companies, bridge fabricators, and welding suppliers to make up the difference, which Morris estimated at $47,000, allowing for the construction of an essentially "free" bridge, at least as far as the taxpayers of Iowa were concerned.

Work proceeded quickly. The Pullman Standard Car Manufacturing Company received the contract to fabricate the girders. By June 1958 Morris, Welden, Ashton, and the chief engineer of the highway commission, John G. Butter, were at the Pullman factory in Chicago, inspecting the nearly finished product. Once the Pullman plant completed construction of the girders, the entire structure was loaded onto four flatcars and shipped by rail to within two miles of the site. It was then hauled by truck over the interstate right-of-way and hoisted into place. Work was finished by August 1958, and the bridge was opened and formally dedicated on September 24, 1958.

Despite the novelty and success of the project, the use of aluminum as a highway material remained limited, and only three other bridges using aluminum were built in the country. Shortly after the opening of the Des Moines bridge, New York built two aluminum riveted girder bridges. In 1961 Virginia completed the Appomattox River bridge at Petersburg. However, the price of structural steel fell throughout the 1960s, reducing the need for an alternative material, while the price of aluminum remained high.

Bridge deck
Here, work on the deck of the Northwest 86th Street bridge, built conventionally, is well underway.

The completed bridge, nearly ready for traffic



Eventually, Iowa's aluminum bridge became a victim of progress. Although it gave good service for 35 years, the bridge was too small to serve an improved 86th Street interchange and was replaced in 1994.

The final inspection reports for the bridge in the 1980s and early 1990s noted that some cracks had developed in welds. No evidence was found, however, of any cracks or failure brought on by fatigue in the structure itself. Of greater concern were several gouges in the bottom of the girder structure. These were caused by over-height loads scraping the bottom of the bridge. Such gouges, if left alone, might develop into cracks and further damage the structure and were therefore carefully ground out whenever they appeared. Although the aluminum structure was in good shape when it was removed in 1993, the same could not be said for the concrete deck, which had deteriorated considerably over time.

Passing the flame

In 1960 Mark Morris retired from the Iowa State Highway Commission. His talent was too valuable to dispense with altogether, and so he remained as a consultant until 1963. During his tenure as director of highway research and secretary to the Iowa Highway Research Board, he had seen the creation and development of the Board. In 10 years, 71 projects had been undertaken, including several of national significance, and the Board had expended $2,700,000.

Morris was succeeded by Stephen E. Roberts. With Roberts, the Board began to develop a systematic agenda for highway research in Iowa, which would mark a new era.

The Justification of Research

Stephen E. Roberts, who succeeded Mark Morris as secretary of the Iowa Highway Research Board, encouraged the Board to move in new directions. Several innovations occurred during his 15-year tenure.

Roberts was born in Burlington, Iowa, on November 10, 1918. Upon his graduation from high school, he attended a business college for one year and then worked in the office of the Midwest Biscuit Company. In 1942 he enlisted in the Army Air Corps and served as a finance clerk in Tunisia, Italy, France, and Germany. The end of the war provided him with new educational opportunities, and in January 1946 Roberts enrolled at Iowa State College in the general engineering program. This curriculum provided no specialization but rather an exposure to a wide variety of engineering disciplines. It proved to be useful training for a research engineer, which is what Roberts became when he graduated from Iowa State College in June 1949.

Roberts was immediately hired by the Iowa State Highway Commission. He began in the materials lab, performing tests. He then worked on special problems and rose to the position of assistant laboratory director. In 1958 he was promoted to materials engineer for District 1. Upon Morris's retirement in 1960, Roberts was appointed the research engineer.

Roberts encouraged the Iowa Highway Research Board to consider not only the research projects immediately before the Board but also the formation of a research agenda or policy. In May 1960 he suggested that "sometime soon" Board members should discuss the general subject of research and develop some ideas for research in specific areas. Such a formulation of a research philosophy had not previously been explicitly undertaken by the Board. Later that year Roberts would begin the discussion with a summary of his ideas and then encourage members of the Board to respond. His remarks would lead to presentations by members of the Board on the role of the university in highway research, the objectives of county engineers in the conduct of research, and the desires of highway commission engineers in facilitating research. Unfortunately, no extended notes of this last presentation have been preserved in the files of the Board.

Stephen Roberts
Roberts, shown at his desk in September 1965, was research engineer and secretary to the Iowa Highway Research Board from 1960 to 1975. During his tenure, formal consideration was given for the first time to a research agenda or policy to guide the funding of proposals.

The Iowa method of bridge deck repair being demonstrated in the 1970s
This method, which allowed the refurbishing, rather than the complete replacement of bridge decks, generated significant savings of both time and expense.

A friendly debate

In August 1961 Roberts opened the discussion by encouraging Board members to carefully consider the purpose of highway research. The immediate cause for his concern was the appearance before the Board of half a dozen proposed projects which, between them, would consume one third of the available budget. This impelled Roberts to suggest that the Board "review some of the ideas which I believe should be considered in judging the merits of all research proposals submitted to the Board." Roberts was careful to emphasize that he was merely presenting his personal opinion. The opinions he expressed, he hoped, would provoke members to think about the work of the Board and about highway research overall.

Roberts suggested that research could be justified in at least two ways. Research might be used "in order to increase our knowledge of ourselves and our universe without regard for any immediate application of that knowledge." By contrast, industry research had as its justification the discovery of new products or improved industrial methods. Research could be justified, then, by either improvements in general knowledge or improvements in practical methods. Roberts noted, however, that highway research funds in Iowa were derived from money dedicated to highway construction. In the final analysis, this fact provided the only possible justification for Iowa's highway research program. Research sponsored by the Board, to be justifiable, had to contribute to "the construction and maintenance of better or more economical highway facilities."

With such justification in mind, Roberts suggested that possible research projects could fall into three categories: problem solving, new ideas, and fact finding.

"Problem solving" research could be defined as inquiry aimed at solving perceived shortcomings in existing methods. This research would lead directly to improvements in technique. In consequence, problem solving research proposals were most likely to be justifiable to the Board if the shortcomings in existing knowledge seemed important enough.

"New idea" projects were somewhat more problematic in Roberts' view. Such projects involved the investigation of materials or methods not presently used in highway construction or maintenance and were more difficult to justify than research designed to solve existing problems. Some proposals could be readily linked to potential improvements in highway construction, but some proposals, while potentially interesting, were too detached from the improvement of the highway program to be justified.

"Fact finding" projects did not necessarily involve engineering problems. Rather, fact finding projects focused on investigating tangential issues to improve the highway program in other ways. The compilation of highway laws, for example, while not leading to the improvement of materials or methods, improved the overall efficiency of highway officials. Other fact finding research could sometimes be justified if the Board felt a need to accumulate knowledge on a subject. The Board had funded such projects in the past and would do so in the future.

Roberts stressed the need not only to carefully justify research expenditures but also to ensure that results found their way into practice. Consequently, the Board might have to fund further development of promising initial research results to guarantee their applicability. For example, the Board might find itself being asked to fund field trials of experimental methods or materials.

Roberts' suggestions were part of a more extensive effort to systematize the work of the Board. Some proposed projects that could not be justified using criteria similar to those articulated by Roberts were rejected. HR-1, the long-running investigation of Iowa soil types, was ultimately discontinued as having resulted in no applicable results for highway construction.

Discussion of Board methods continued. In May 1964 D. R. Boylan, an alternate member of the Board (and later dean of the engineering school at Iowa State University, previously Iowa State College), delivered a paper to the Board entitled "The Role of the University in Highway Research." Boylan suggested that the university had a duty to undertake research. He argued that practical research allowed the university to "pay back, in part, the debt that educational institutions owe society." Despite this obligation, the potential role of the university in highway research offered both considerable potential and severe limitations.

The limitations imposed on the university stemmed from its other role as an educational institution. As a result, Boylan contended, university research was confined to projects that were "a) academically oriented, b) moderately long-term, and c) adaptable to available manpower and facilities." From the university's point of view, projects should be suitable for training graduate students or sufficiently novel to entice academic staff. The project should be of sufficient duration to allow for the orderly employment of staff and resources; "crash" efforts were not usually feasible due to preexisting commitments of staff and resources. Finally, projects would have to be structured to take advantage of preexisting university equipment or funded to allow purchase of all required equipment.

Notwithstanding these significant limitations, Boylan contended the university could still play an important role in highway research. The university was uniquely suited, he said, to serve as a font of new ideas, a source for specialists not usually available to the highway commission, and an institution to recruit and train new research personnel. Boylan pointed out that specialized laboratories such as the hydraulics laboratory at the University of Iowa and the soils, bituminous, and structural research laboratories at Iowa State University had provided valuable assistance to the Board in the past and would continue to do so. He also noted that other departments offered similarly useful contacts.

Boylan concluded by suggesting that the model for further highway commission/university research links should be drawn from the then novel concept of the "research team." Boylan pointed to the existence of university/industry teams then in operation. The advantage of such teams, Boylan suggested, was that they would allow both the university and the highway commission to draw from their appropriate strengths. The practical result would be that both parties would identify research problems and furnish some of the resources necessary for solution. Boylan cited one example in which Iowa State University supplied personnel and mathematical analysis of data and the industrial partners supplied equipment. Such an approach would move the Board beyond being a patron of research into a more active role.

Input from the Iowa county engineers followed from W. G. Davison, president of the Iowa County Engineers Association. In a paper delivered to the Board on August 28, 1964, entitled "Suggestions to the Iowa Highway Research Board," Davison offered his views on two questions. First, he asked, "What type projects would be of the most benefit to the Counties for use on Secondary roads?" Second, he asked, "How may proposals for research projects benefiting Secondary roads best be obtained?"

In discussing the utility of topics for research, Davison analyzed the amount spent by counties on secondary road systems. He estimated that maintenance budgets tended to absorb 45 or 50 percent of available funds. Construction, he thought, consumed 40 or 45 percent. Engineering and administration absorbed the balance, about five or six percent.

Davison suggested that this allocation might furnish a guide to the Board's allocation of resources. If maintenance absorbed a large portion of county budgets, perhaps a large portion of the Board's attention should be devoted to developing new methods by which counties could economize in their maintenance budgets. Davison conceded that the best way to reduce maintenance costs was to develop better methods of construction. Still, he observed, the study of ways to reduce maintenance expenses, for example by sharing equipment or personnel between counties or between the state and counties, might be worthy of the Board's attention. In considering such projects, Davison observed, the "main objective should be to provide the State of Iowa with the best overall highway system at the least cost possible."

Davison noted that the National Association of County Engineers was then engaged in developing a standard for maintenance practices and a manual. He anticipated that this would standardize many operations and result in significant savings for counties. Many research topics would be covered in the manual, and the Board might not find it necessary to engage in duplicate research efforts. Still, Davison anticipated that many questions worthy of attention would remain for the Board.

Construction technique, given the amount of county road budgets that it consumed, would afford another fertile field for Board review. Davison offered three areas of interest related to construction technique for the Board's consideration. Davison wished to see the Board develop research based on the work of the American Association of State Highway Officials (AASHO) on pavement thickness. He hoped that the Board would investigate the problem of surface types for low-volume roads. Finally, he suggested that the Board should continue to investigate new methods of dust control.

One immediate benefit, Davison argued, could be realized from a thorough Board review of road test experiments conducted by AASHO to determine the applicability of AASHO's research to local Iowa conditions. The AASHO tests appeared to contradict minimum standards for pavement and base thickness laid down by the Iowa State Highway Commission. State minimums for thickness design allowed for no variation based on pavement type. AASHO experiments, on the other hand, indicated that significant variability in equivalent thicknesses existed. Davison continued, "either the tests were of no value to Iowa, or we should be making use of them. Whichever the case may be, I believe this Board should see that the full information is made available for use in design."

Another area of research interest, Davison argued, was the economic justification of surface type. Surface types for low-volume roads was an area of interest not only to county engineers but also to city and state engineers. Given the broad level of interest in this subject, it appeared to have promise for Board investigation.

Similarly, Davison continued, the Board would be well served by engaging in further investigation of dust control. Such studies were useful from more perspectives than "the viewpoint of the Monday Washday housewife." Vehicle safety was implicated if the dust was so intense that drivers could not see.

Less significant achievements were to be gained from engineering and administrative studies, Davison observed. The highway commission expended approximately the same proportion of its budget on engineering and administration as the counties did in those areas. Given that the highway commission had a well developed system for engineering, not much in the way of economy could be expected.

These mundane questions, Davison believed, were of great interest to practicing county engineers working on secondary road systems. He pointed out that significant differences in opinion existed among his colleagues. Research aimed at removing those differences of opinion would be very useful. Davison suggested that such effort should be predominant on the Board's research agenda. In an implicit criticism of then-pending research proposals, Davison noted that his suggestions might seem "insignificant questions to a Board concerned with such high-minded research as 'X-Ray Diffraction Studies of Soil and Soil Stabilizers,' or some of the others recently proposed."

Davison then turned to his second question, determining the best method for obtaining research proposals that would benefit secondary roads, which he found far easier to answer. He noted that research proposals were easily obtained. County engineers on the Iowa Highway Research Board attended district meetings of their state association at least annually. At those meetings, "shop talk" discussions or more formal presentations generated ideas that were worthy of further investigation. It would be easy for Board members to give presentations at association meetings regarding the then-pending work of the Board and to solicit research topic proposals.

Davison concluded his presentation by praising the Board for the work it had financed in the area of hydrology and structures. He hoped that the Board would continue its fine work in that and other areas. He also promised the support of the Iowa County Engineers Association in ensuring that the Iowa General Assembly made secondary road money available in the 1965 session.

By 1964 the Board found itself seriously in need of the Iowa County Engineers Association's support to justify its research expenditures; the Board's authority was undergoing serious legislative attack.

A not-so-friendly threat

After the Board's inception in 1949, its statutory authorization had remained unchanged for several years. Then in 1961 the Fifty-Ninth Iowa General Assembly repealed the Secondary Road Research Fund, which funded much of the Board's research activities. At the same time, the assembly amended Chapter 312 of the Code of Iowa dealing with Iowa's road use tax fund to include expenditures for research. Assuming that its authority was continued under the revised Chapter 312, the Iowa Highway Research Board continued business as usual.

In 1963 the Board's authority was called into question by Representative Dewey Goode (R-Bloomfield), who requested an attorney general's opinion. The resulting opinion effectively eliminated any further expenditures from the road use tax fund for secondary road research; as of January 1, 1962, only primary road research could be undertaken. The opinion stated that unused allocations before that date remained available for researchers at the Iowa State Highway Commission.

This situation continued until 1965. When the Sixty-First Iowa General Assembly met that year, it restored the Secondary Road Research Fund in House File 424 and again, as in 1949, allocated up to one and one-half percent of the farm-to-market road use tax fund for planning and research. Balances left in the fund at the end of any fiscal year could be carried forward into the next year. Since the appropriation was, in effect, open-ended, the highway commission allocated a minimum of $125,000 per year for secondary road research.

Although the general assembly did not long delay in restoring funds after the attorney general's adverse opinion, the matter was of great concern to the Iowa Highway Research Board. Board minutes during the legislative sessions indicated that regular progress reports were received on House File 424, as well as on a previous, similar bill that failed passage and on a legislative proposal to abolish the Secondary Road Research Fund altogether. The temporary loss of funds impeded some Iowa Highway Research Board efforts. For example, in 1963 counties wishing to participate in a traffic survey to be partially funded with federal matching funds were unable to look to the Board for assistance. Instead, they were compelled to supply their own money in order to qualify for the federal funds.

A productive era

Perhaps as a result of criticism posed by county engineers like Davison, as well as the more aggressive threats posed by legislators like Goode, the Iowa Highway Research Board modified some of its practices. Fewer basic science proposals were approved. The highway commission began to conduct more of its research in house and looked less to outside contractors. Some long-running research proposals that promised better design methods, such as those related to hydrology and flood magnitude, were continued, albeit under greater Board scrutiny. Other projects came under increasingly critical review by the Board and were cut short.

In 1960, even before the Board found itself deprived of Secondary Road Research Fund money, the matter of the long-running project investigating Iowa soil types, HR-1, was taken up by the Board. The result of the project had been similar to the results of soil research pursued by the U.S. Bureau of Public Roads: Much basic knowledge was uncovered, little of which was immediately useful in the design of better or more economical roads. In 10 years, HR-1 had led to the publication of 64 separate academic papers given at conferences or published by the national Highway Research Board or by Iowa State College. Despite this prodigious academic output, the Iowa Highway Research Board had received no final report and had distributed no information related to HR-1 to county engineers and the highway commission staff.

When the project supervisor, D. T. Davidson, requested a funding extension, his request met with stiff opposition. V. R. Bennion, a Board member serving for the State University of Iowa and employed by the U.S. Geological Survey, asked if it might not be possible to begin work on a final report. Davidson replied that this was inadvisable, as much of the research was still incomplete and the task of simply compiling the information gathered to date would require his full time for a year. D. R. Boylan of Iowa State College suggested that a special compilation of the published papers, grouped by subject, might be put together and distributed. M. B. Larson, an alternate member of the Board for the highway commission, pointed out that the object of the research was to make information available to county and highway commission engineers in a useful form. John C. Mors, another Board member, expanded on this theme by pointing out that the act creating the Secondary Road Research Fund directed that the fund was to be used for investigation and improve-

ment of materials used on secondary roads. If that was the justification of HR-1, it was vital that the information gained be put to the test in field trials through the construction of experimental roads. Without such field trials the research was of little use, Mors argued, as the accumulation of knowledge was in itself inadequate. In the end, HR-1 carried on a while longer, although in a much reduced fashion.

Other projects pursued by the Board had happier outcomes.

In November 1960 the Iowa Highway Research Board approved HR-74. This project furthered the construction of a bridge designed to include prestressed steel I-beams. The bridge, the first of its kind in Iowa, was located on U.S. Highway 6 in Pottawattamie County. The highway commission viewed the project as a good opportunity to give as many steel fabrication contractors as possible experience with the new method of construction. To obtain the steel required, the highway commission turned to the Iowa Highway Research Board for the purchase of the required beams as a research project. The balance of the project was handled by the highway commission in the normal fashion.

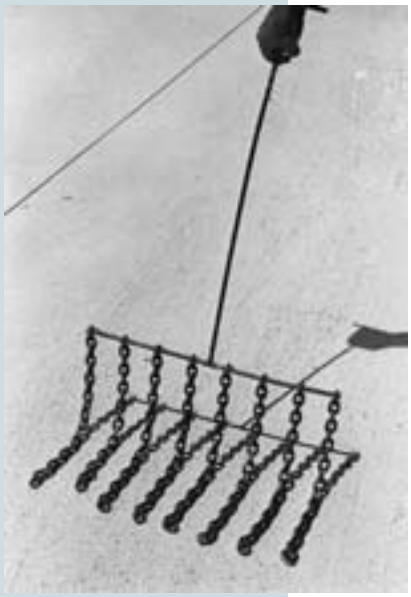
In 1964, as debate continued over the nature and extent of the Secondary Road Research Fund, the Iowa Highway Research Board approved HR-95, "Repair and Protection of Concrete Bridge Superstructures." This work was the foundation for later work that resulted in the development of the dense concrete overlay technique, which solved a major bridge maintenance problem, saved Iowa counties and the Iowa State Highway Commission significant monies, and spread across the country.

Ice on bridges had traditionally been combated with salt. This treatment melts the ice but leaves a corrosive salt brine on the road surface. The brine can penetrate concrete bridge decks, causing deterioration of the deck and of the steel reinforcing bars below. Eventually, the whole structure is weakened. Before the findings of HR-95 were made available, such conditions would have led to a bridge's closure for replacement of the entire deck, at great expense and no small inconvenience to the public.

The bridge research project experimented with a partial repair solution developed by the highway commission's John Lane and Ed O'Conner. A bridge in Sac County was selected for the test. Instead of replacing the deck, researchers removed concrete to a depth of about a quarter-inch, together with any defective concrete and concrete around the reinforcing bars. The exposed steel was sandblasted clean. A fast-setting concrete was then poured, spread, and smoothed. When the concrete cured, the bridge was reopened for traffic. This method was both faster and cheaper than a complete deck replacement.

The experiment proved successful, and the "Iowa method" of low-slump, dense-concrete deck overlay construction quickly spread throughout the United States. The cost to the Iowa Highway Research Board was $19,000. Vernon Marks, successor to Stephen Roberts as secretary of the Board, estimated in the mid-1980s that the savings to the taxpayers of Iowa alone had been, by that time, about $30 million based on the cost difference then existing between resur-

1970s Iowa method of bridge deck repair



An experiment
A metal device, itself experimental, used for determining corrosion and deterioration in a bridge deck. Inspection by sound was time-consuming but effective.

facing and deck replacement. He also described the work as the single most useful project the Board had undertaken.

In October 1975 the Board had occasion to revisit the issue of bridge repair when the successor agency to the Iowa State Highway Commission, the Iowa Department of Transportation ("DOT"), proposed research entitled "A Bridge Deck Delamination Study" through the Office of Materials. The Iowa Highway Research Board approved the proposal as HR-179. Corrosion caused by salt required periodic inspection for detection of delaminations and maintenance planning. Initially, inspections were conducted by tapping the bridge with metal. Such an inspection required a crew of four people for testing and traffic control, and the entire procedure might take eight hours. The method depended on inspectors' ability to hear the tapping and so was entirely subjective—an art rather than a science. In 1975 a firm in Texas offered for sale an electronic device that allegedly could record delamination data for a bridge on a paper chart in one hour. Its curiosity aroused by this claim, the Iowa DOT proposed to pchase a prototype for $7,700.

A "Delamtect" device ready for use
This machine was used to speed up delamination studies and reduce the amount of time spent by bridge crews. The Iowa Highway Research Board funded evaluation of the machine.

The equipment worked, giving rise to a great savings in time and leading to a more scientific method for analyzing bridge repair needs. A subsequent project, HR-269, enabled the computer plotting of the data collected. This saved more time for the bridge maintenance crew by eliminating the labor-intensive mapping of paper charts.

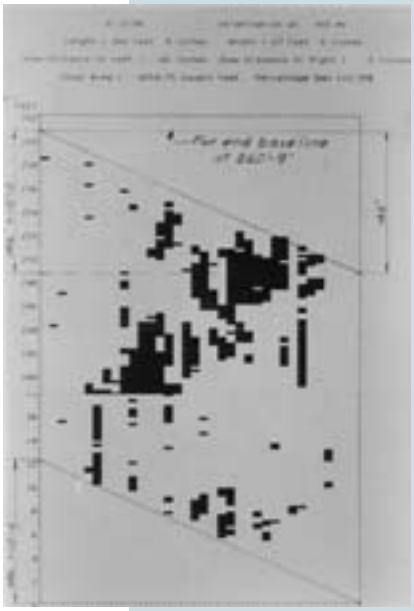
In 1969 the Board approved HR-148, which called for an investigation of pavement wear caused by studded snow tires. Studded tires, useful for winter driving conditions, were first legalized in 1967. The tires quickly became very popular in Iowa and by 1970 were used on over one-fifth of all vehicles in the state. This research project examined pavement wear caused by the tires. The results were astonishing. Based on wear measured during the winter of 1970–1971, researchers estimated that studded tires would be responsible for an additional $140 million in road maintenance on primary and interstate highways over a period of five years. The research did not lead to an immediate ban on the use of studded snow tires, but publication of the discovery—coupled with a legislative attempt in 1972 to seasonally restrict use of the tires, and the introduction of radial tires—was sufficient to discourage public use of the tires, the popularity of which fell precipitously.

New materials were also investigated by the Iowa Highway Research Board. The early 1970s saw an increase in the price of asphalt, causing engineers and contractors to cast about for alternatives. In January 1975 R. P. Henely, the Kossuth County engineer, presented a research proposal to investigate the possibility of recycling

asphalt pavement. Henely proposed to pave a section of road nearly one mile long, widening the shoulder and paving a preexisting 22-foot pavement with a seven-inch thick asphalt surface on a four-inch thick subbase. The old asphalt was to be gathered, crushed, and reused. New asphalt cement, amounting to about one percent of the total to be used, would be added. The whole project was expected to cost about $98,000, and Henely requested that the Board furnish about $70,000 of that amount. The Board approved the project at a cost of 50 percent of the total, not to exceed $50,000, contingent on the delivery of appropriate plans and specifications by Kossuth County.

This work marked the first of several research projects involving the recycling of asphalt and the performance of recycled asphalt construction. The discovery that asphalt could be practically recycled allowed for significant cost savings. One potential drawback, the copious air pollution caused by the Kossuth County project, formed the basis for a further investigation, taken up in HR-188.

Stephen Roberts concluded his service as secretary of the Iowa Highway Research Board in December 1975. During his tenure, the Board had undertaken many projects of vital significance. It had been expanded in 1969 to include representation for municipal engineers. Extensive discussion of the purpose of the Board and of the purpose of the research it supervised had precipitated the development of a philosophy or research agenda focusing on practical, applied research rather than on theoretical developments. Challenges to the existence of the Board had been unsuccessful. Under the successors to Stephen Roberts, the Board would build on previous accomplishments and continue to fund highway research leading to significant advances in engineering methods.



Delamtect machines
The earliest Delamtect machines printed data on rolls of paper similarly sized to those used in an adding machine. Analysis took considerable time. Iowa Highway Research Board research allowed the development of computer programs to locate and map delaminated areas, thus further accelerating bridge inspections.

The Fruits of Research

In December 1975 Stephen Roberts retired as secretary of the Iowa Highway Research Board. He was succeeded temporarily by Fred W. Walker. Walker had risen to the post of development engineer for the Iowa DOT's Office of Operations Research. He was, in effect, the number-two man in the department's research structure. As such, he served as secretary to the Iowa Highway Research Board through all of 1976, until a permanent successor was found for Stephen Roberts.

Identifying useful research

During Walker's brief tenure as secretary to the Board, Board member R. H. Given proposed in March 1976 that committees be established to seek useful new research proposals. Given suggested that the committees identify research topics in their areas of appointment, define problems associated with the topics, and prepare recommendations for possible research projects based on those problem statements. The research areas that Given proposed for the committees were grading, pavements, structures, and other research. After some discussion of the idea, the motion was withdrawn. The minutes of the Board offer no explanation for the withdrawal; perhaps consensus was reached and formal action became unnecessary. In any event, the committees were ultimately appointed and existed for several years. During those years, the committees suggested several possible research ideas for consideration.

At the same meeting, a general discussion of potential research areas led to four particular items being described as of immediate interest to the members of the Board. These subjects were pavement markings, the utility of slurry coats, macadam shoulder construction, and the effect of one type of seal coat aggregate. The Board decided to actively solicit research proposals in those areas.

Proposals for research in these areas quickly followed. At the April 1976 meeting, research proposals for each area of interest were proposed by members of the Board. The investigation of the slurry seal coat was the first of the topics to be reduced to a proposal and discussed, with Board members relying on Iowa DOT staff for further preparation. Funding was approved, and both the University of Iowa and Iowa State University were invited to apply for the grant. Iowa State University ultimately conducted the survey. During Walker's brief tenure, the foundation was thus laid for some significant studies and for a new way of bringing research ideas before the Board.

Vernon Marks
Marks succeeded Stephen Roberts and the interim secretary of the Board, Fred Walker, in 1977. During Marks' tenure, many advances were made in construction methods and in ways to apply computerization to highway research and construction.

Slurry seal in progress
In 1976 experimentation concerning the application and utility of slurry coats was a subject of interest to Board members. The Board funded several projects involving the use of the technique.

Computers and more

By December 1976 the permanent replacement for Stephen Roberts had been hired, and Acting Secretary Fred Walker was replaced by the new research engineer, Vernon Marks. Marks would serve in that post for 21 years, from January 1977 to June 1998.

Marks was born on May 30, 1936, at Ord, Nebraska. When he was four his family moved to Iowa, settling south of Des Moines. He graduated from Indianola High School in 1955, and from Iowa State University in 1960 with a bachelor of science degree in civil engineering.

After a year in California as engineer-in-training for the County of Los Angeles Road Department, Marks returned to Iowa where he became the assistant materials engineer at the Iowa State Highway Commission's district office in Atlantic. In 1967 he moved to the department's central offices in Ames. There he served as special investigations engineer, specializing in pavement evaluation, testing, and management, until he was appointed research engineer in 1976.

Marks believed that engineers should always be looking for innovative ways to improve quality and reduce costs. That conviction, together with a natural curiosity and a strong work ethic, earned Marks a national reputation as a diligent and productive research engineer. From 1988 to 1994 he chaired the Transportation Research Board's Committee A2H03 on Mineral Aggregates; he has served on several National Cooperative Highway Research Program project panels; and he has been an active participant in national expert task groups and Transportation Research Board councils.

During his tenure as secretary of the Iowa Highway Research Board, the Board would undertake many projects of profound significance. It would develop new tools for use in the computer age. It would adapt new technology for the testing of materials and for the construction of roadways. It would face new concerns and move into completely new areas, such as legal research. And it would explore policy issues and issues concerning the well-being of the engineering profession. In 1989, the Street Research Fund was created for the conduct of research relating to city streets.

The late 1970s and 1980s saw increasing use of computers in all aspects of life. The Iowa Highway Research Board had long supported research that extended the computer "revolution" to engineering work, especially county engineering. As the 1980s progressed, the Board became more involved in computerization and technology research. Many of these projects led to computer programs that improved the productivity of engineering staffs.

By the time Marks assumed duties as the Board's secretary, the Iowa Highway Research Board had already sponsored research on a computerized program to assist the hydraulic design of culverts. In 1968 the Board had sponsored HR-143, a computer program to determine the amount of cut or fill required by a project from field observations. In September 1980 some refinements to the program were proposed. The object was to allow the program to calculate changes in grade and elevation and to allow data for different types of pavement surfaces to be used. This project took some time to come to fruition.

In September 1983 a sweeping proposal was made to develop, test, and evaluate computer applications for use by highway agencies. The proposal included efforts to train county engineers and their staffs in the use of the programs developed or tested. Several specialized applications emerged as a result of the Board's effort. One example of such work is HR-284, which developed a set of spreadsheets specialized for use by county engineers and another spreadsheet for hydraulic calculations.

Beginning in 1988 Iowa Highway Research Board funding enabled researchers to find new ways for both the Iowa DOT and county and municipal engineers to take advantage of global positioning systems (GPS) and geographical information systems (GIS) technologies. Projects were funded that used these new technologies for improved mapping and surveying efforts.

More computer research proposals followed in the 1990s. Proposed federal standards in 1991 led to the development of a bridge maintenance management database designed to allow for the efficient allocation of maintenance resources.

In September 1992 HR-345, a proposal to develop an electronic bulletin board for Iowa's county engineers, was approved. The system allowed the Iowa DOT to post bulletins and updates and to furnish resources electronically. County engineers could communicate with each other, as on any other bulletin board, and post questions. The Board hoped that the accumulated responses would furnish a valuable reference guide in its own right. The project started slowly as a test but steadily grew in popularity until it was replaced in 1998 by an Internet service, the Iowa County Engineers Association Service Bureau.

Legal issues

The Iowa Highway Research Board had always funded projects concerned with law. In fact, one of the early projects by the Board in the 1950s was a compilation of Iowa's state highway laws. That compilation having proved popular, a codification of the state drainage laws was undertaken. Compilation projects continued to be funded periodically thereafter. The assistant attorney general for the Iowa DOT periodically obtained grants from the Iowa Highway Research Board to prepare revisions of the state traffic law compilation. The state drainage law, perhaps being less fluid, was not recompiled. To these works were added two more projects supervised by the Board: manuals for the guidance of county and city officials generally, and engineers in particular, regarding condemnation policy and practice. These manuals were designed to explain the very complex subject of eminent domain to county engineers dealing with right-of-way acquisition.

Another legal subject of interest to the Board was the increasing liability for maintenance practice on highways. With the abolition of sovereign immunity in the 1960s, political subdivisions became inviting targets for much tedious litigation. Finding new ways to defeat litigation became a favorite topic for Board investigations. The first such study, HR-204 in June 1978, was initially entitled "Corrective Action by Counties to Minimize Potential Liability for Highway Accidents." On the advice

Iowa Highway Research Board meeting
This meeting, one of the few photographed in progress, occurred sometime in the late 1970s.

of counsel, the title was changed to "Safer Construction and Maintenance Practice to Minimize Potential Liability by Counties from Highway Accidents." The investigation proposed to survey and analyze county tort claims experience and then formulate recommendations. The study centered on the role of guidelines, sign maintenance, and proper sign placement. The survey discovered that significant, if sporadic, liability hazards existed. The final report on the project cautioned county engineers not to commit their practices to writing lest they invite a round of liability problems. One Board member was so concerned that the study might exacerbate liability problems that he was initially reluctant to fund it.

Such fears do not appear to have been misplaced. On September 28, 1982, an associate of Vern Lawyer, then a prominent Des Moines litigation attorney, came to the Iowa DOT administrative offices in Ames. He copied Board minutes from 1974 to 1982. He also requested copies of files concerning rumble strip research (HR-184 and HR-235) and the liability research (HR-204). No indication in Board minutes or files, however, shows that Lawyer ever used the material gathered in a lawsuit, so the reason for Lawyer's interest is unclear.

Other liability-related research quickly followed and was supported by the Board. Liability issues for rural subdivisions were examined. Liability for the maintenance of low stream crossings was considered. Other traffic safety oriented research was partly aimed at the liability problem. Throughout this research, the goal was to identify roadway hazards most likely to lead to injury and litigation. Counties could then, by attentive and competent maintenance, remove those hazards and reduce the chance of injury.

The county engineering profession

The Board undertook some efforts aimed at the well-being of the engineering profession as a whole. The job satisfaction of public engineering was examined. A study aimed at finding ways to bring women and minorities into the engineering profession was undertaken. The role of the engineer in the county decision-making process was examined. In 1994 the Board began to fund the expenses of two county engineers to attend the national Transportation Research Board's (previously the national Highway Research Board) annual meeting in Washington, D.C. It was hoped the trip would expose the engineers to national research and increase interest in the subject. It was also hoped that the engineers would obtain new professional contacts, exchange ideas, and begin to formulate research proposals on their own. This program has been a great success and very economical.

Other projects

Several proposals for basic research, albeit using some very complex technology, were also presented to the Board throughout Marks' tenure. An extensive study of ice removal led to several projects and proposals. The work began with the question of how plows break and move ice and then developed the first accurate model of how blades clear ice. This research led to further questions until it resulted in a project to design a computer-assisted plow incorporating the new information learned.

"X-Ray Analysis of Carbonate Aggregate to Predict Concrete Durability," HR-266, provided insight into the properties of a good aggregate for portland cement concrete. This study added considerably to knowledge of the life span of portland cement concrete and allowed for predictions to be made about the suitability of aggregates for a concrete mix.

Another project, HR-380, concerned itself with the curing of portland cement concrete, which had not been well studied. Usually, new concrete pavement was allowed to cure for five to 14 days before being opened for traffic. The length of time was not based on any scientific notion or on any possibility for acceleration. In cases where traffic needed to move immediately, a long curing time was not always possible, and therefore interest in shortening the period was great. Resulting from a need to open a road quickly in Lee County, Iowa, this project developed the maturity method for estimating concrete strength. This method allows builders to shorten the minimum curing time to as little as two days.

Image analysis testing, explored by the Board in HR-396, allowed for better quality control for concrete. Image analysis allowed the rapid examination, quantification, and analysis of any number of subjects. A wide variety of items could be analyzed using the image technology, including air voids in concrete as studied in HR-396.

Finally, HR-401 on the quality of soil used in embankments sought to develop design standards for embankment soil compaction through study of embankment failure and its causes. Classification of those causes could then allow for adjustments to compaction procedures during construction.

In June 1998 Vernon Marks retired after 21 years as secretary to the Iowa Highway Research Board. He was succeeded by Mark Dunn. Dunn was born in Marshalltown, Iowa, on September 9, 1970. Given his talent for mathematics and science, he gravitated towards engineering and received his degree in civil engineering from Iowa State University in 1993. Upon graduation, Dunn began work at the Iowa DOT in the bridge design department where he stayed for five years. Dunn views his appointment to the position of research engineer as fortuitous in that it allows him the opportunity to deal with a variety of different subjects on a regular basis.

At the present time, the Board has active projects in many areas, including embankment erosion (TR-401) and bridge deck cracking (TR-405), which seem likely to yield significant results. Dunn foresees future opportunities for Board research in two areas. The further development of innovations in alternative materials for use in highway construction affords ample scope for research proposals. Also, problems faced by county road departments in the maintenance and replacement of aging bridges during a time of budgetary constraint provide considerable opportunity for work on novel bridge construction and repair solutions. While other areas of research will doubtless come to light, those two fields alone may well engage Board attention for many years to come.

Mark Dunn
Dunn succeeded Vernon Marks as Secretary to the Iowa Highway Research Board in 1998.


NO
PASSING
ZONE

The Dissemination and Significance of Research

Research without dissemination of results is not very useful. Since its inception, the Iowa Highway Research Board has exerted considerable effort to ensure that its work has received the attention of the county engineers for whom the Board was formed. Additionally, the Board has statutory obligations to report to the governor and to both houses of the Iowa General Assembly concerning its work. The Iowa State Highway Commission and its successor, the Iowa Department of Transportation (Iowa DOT), have found it worthwhile to ensure that the Board receives public recognition for its work. Board members and Iowa DOT research directors present research at professional conferences. Other professional contacts have developed to allow the Board to both receive and deliver information.

Getting the word out

In the Board's early years, county engineers received information resulting from Board projects in the form of bulletins. The first of these bulletins was a survey of loess soil literature. Others followed. Occasionally, the Board would publish the bulletin. At other times, the agency conducting the research would publish the bulletin. Additionally, Board projects quickly began to be discussed at meetings of the Iowa County Engineers Association. At the December 4, 1951, Board meeting, the Board was asked to furnish a half-day program for the association's conference. Four papers were selected for presentation. D. T. Davidson gave an address on HR-1. V. R. Bennion reported on the determination of flood discharge, work derived from HR-3. HR-7, a proposal for a test track, was discussed by Ladis Csyani. Mark Morris discussed Maryland's system of test roads.

Reports to the governor and the Iowa General Assembly furnished another source of information about Board activities. These reports summarized each project then underway. The cost of each project was noted, together with its funding source. Investigators were noted, as were the accomplishments of the program and its budget.

The work of the Board initially received some public attention. In December 1950 one Board member attended an Iowa Good Roads Association convention and delivered a report on the work of the Board. This was followed by questions from city engineers about the possible participation of municipalities in research. Another member, Ladis Csyani, appeared on WOI television at least twice in the early 1950s to demonstrate research funded by the Board. Visits by the Board to experimental construction projects did not go unnoticed. Frequently, members were met and escorted by county boards of supervisors.

Equally significant were highway commission (later, Iowa DOT) attempts to interest the public in the work of the Board. In 1960 research on culverts led to a prominent illustration in the highway commission's annual report. A description of the savings achieved by the new method accompanied the diagram. Thereafter, research projects calculated to reduce costs to taxpayers or to improve highway safety were routinely included in the annual report of the highway commission.

No passing
The Iowa Highway Research Board funded studies of traffic signs in an attempt to improve highway safety. The "no-passing" sign was an Iowa State Highway Commission invention that gained national acceptance.

Immediately after the Board was formed, it was occasionally visited by engineers from other states seeking information about the formation of similar boards. The Board was visited by officers from both Illinois and Kansas. A member of the British Scientific Mission, although not interested in the Iowa model, sought information about research being conducted by the Board.

The Board also benefitted from others' efforts to distribute information. In January 1977 the Board received a copy of a training film on the "Iowa method" of bridge deck resurfacing. The film, produced by Iowa State University and financed with Federal Highway Administration funds, emphasized the results of an important Board project and helped disseminate information about Board-sponsored research.

At different times, the Board helped develop training aids and courses. In 1984 HR-267 was completed. The project developed a training course for snow removal operators on secondary systems. Updated courses on construction standards and the conversion of construction standards from English to metric units followed into the 1990s.

Beginning in 1986 the Iowa Highway Research Board also began contributing significant financial support for Iowa's Local Transportation Information Center (now Iowa's Local Technical Assistance Program, managed by the Center for Transportation Research and Education) at Iowa State University. This Federal Highway Administration-sponsored center was established to assist with transportation technology transfer to Iowa's local government agencies. The Board's funding provided a significant portion of the state and county matching funds required to obtain federal assistance for the program.

Solving problems

Throughout its history, the Board participated in any number of significant project developments, financing the development of new construction methods, new machinery, new maintenance methods, highway safety studies, environmental studies, and dust control methods. The Board helped devise new ways for counties to solve seemingly intractable road problems. Not all the projects led to a useful processes or products, but most were quite valuable.

Among the new construction methods that the Board developed were the use of fly ash in portland cement concrete, the development of foamed asphalt technology, and a recent project to use old railroad flat cars as bridges on low-volume roads. The railroad car project, TR-421, exemplifies the creative work likely to be required of road engineers in the next century. According to the project description for TR-421, Iowa has 27,000 bridges, the third largest number of bridges of any state in the United States, after Texas and Ohio. The vast majority of Iowa's bridges, some 85 percent, are on secondary roads and are therefore the responsibility of county road departments. As present structures age and require replacement, county road budgets may not be equal to the task given the large number of structures requiring attention. One possible alternative for infrequently used roads is the conversion of railway flat cars into bridges. Rail cars offer the advantages of low cost, ease of installation, durability, and variability of length. One such bridge is already in place in Tama County, and six other states, mostly in the West, have adopted the procedure.

The Board financed a number of new machinery purchases and design developments for the Iowa DOT. In 1979 the Board approved the final report for HR-178 for the purchase and use of the "Road-Rater," a vehicle used to perform load tests on highways.

In 1984 the Board received a report on an issue that had long concerned it, the settlement of pavement on bridge approaches. The pavement on an approach is susceptible to settlement, while the bridge, built on solid piers, is not. Over time the two surfaces may separate, forming a bump or dip where they had previously been joined. This bump is at the least an annoyance to motorists and at worst a hazard. Before this project, repairs of bridge approach bumps were frequently expensive and time consuming. The Board had undertaken a literature search about bridge approach settlement in 1976 by Fred Walker and Dar Fox. Walker and Fox discovered that while many other road departments in the United States and Europe had considered the problem, none had found a satisfactory solution. Here the matter rested until April 1980, when the Board approved HR-219. By May 1984 the research was complete, and the results indicated that several potential, inexpensive repair techniques existed, the most promising of which is the use of flowable fill.

A study of a different maintenance method was undertaken by the City of Des Moines in 1986 under HR-290, "A Study of Ice Retardant Pavement." A salt additive for asphalt pavement, "Verglimit," held some potential for reducing the amount of deicing chemicals used on roadways in the winter. Ordinary traffic use released the salt from asphalt containing Verglimit and left a constant layer of salt on the pavement. Snow, frost, and ice were thus supposed to be removed without effort. The method worked, to a point. While ice formation was impeded, accumulation was ultimately as bad as ever, and the City of Des Moines was unable to reduce the amount of chemicals used on the test area. In addition, during humid summer months the additive caused moisture in the air to condense on the pavement, resulting in a constantly wet surface.

In the field of highway safety, the Board was able to make some significant contributions to the state of knowledge. Three projects exemplify the Board's role in discovering new ways of making driving safer. HR-184, approved in 1976, and HR-235, approved in 1981, dealt with the utility of rumble strips in preventing accidents. The objective of both studies was to accumulate knowledge about the effectiveness of rumble strips in preventing accidents at intersections.

Repeated failures of contraction joint seals in portland cement concrete pavement stimulated the need for research. From 1978 to 1989, three different joint seal projects—HR-203, HR-276, and HR-318—covered various sealing materials, joint designs, and sawing and sealing techniques and ultimately produced some revolutionary changes in joint sealing in Iowa. Because silicone sealants weren't performing satisfactorily, HR-318 was initiated to study the performance of preformed neoprene seals. Findings from this project led to changes in sealant material, joint shape, and sawing techniques, as well as to reduced environmental impacts and costs

Rumble strips
The Iowa Highway Research Board funded two projects to study the effectiveness of rumble strips in preventing highway accidents. Here, rumble strips are being installed. Rumble strips were generally found to be effective in reducing accidents, though one report noted that some drivers occasionally swerved into the opposite lane to avoid them.

and overall improved seal performance. The revolutionary changes—including early, or "green" sawing of concrete, cutting much smaller joints, and filling them with a hot poured sealant—continue to contribute to improved long-term joint seal performance in Iowa.

Environmental concerns increasingly became an issue in the 1970s and 1980s. Many projects revolved around preventing erosion and restoring vegetation. Perhaps the most useful project from a county engineer's point of view was the creation of a revolving fund to obtain archaeological impact investigations. In 1977 the Board received a proposal noting that the Army Corps of Engineers' requirement that archaeological investigations be conducted before the corps permitted the construction of roads caused a hardship for counties with insufficient budgets. As a result, the Iowa Highway Research Board created a revolving fund to finance archaeological surveys with the state archaeologist. Counties could borrow from the fund and would be billed for their share. The fund has been increased periodically and still remains as a valuable part of the Board's work.

Since the 1950s dust control has been a source of interest to the Board. Some dust control projects were attempted in the 1970s. More successful ones in 1986 and 1995 led to better methods of dust control.

A familiar Iowa scene: snowplow in operation The Iowa Highway Research Board funded several projects on ice and snow removal methods, including the development of a model of how plow blades actually remove ice and snow from a road surface. This should lead to more efficient plows and an increase in highway safety.

In 1986 the Board supported HR-297, which promised "Economic Dust Palliatives." The project relied on a limestone additive that was negatively charged. The additive stuck to the positively charged limestone dust, forming larger particles that did not rise. The final report for the project indicated that treating limestone with the additive resulted in a 30 to 40 percent decline in dust over the long term. The second project, begun in 1995 and followed up with a third project in 1997, involved the use of ground asphalt shingles for dust control. In both cases, a nearly dust-free surface resulted, and two years later the surface treated in 1995 showed no significant increase in dust.

Learning from "failures"

Of course, not all promising ideas translated into developable projects. An attempt to build an electronic roadway frost detector was perhaps a bit ahead of its time when HR-187 was launched in 1976. The project was first slowed by a mild winter with very little roadway frost to detect. The device malfunctioned regularly during the next, more severe, winter. The effort was ultimately abandoned.

In contrast, HR-180, also approved in 1976, was nearly a victim of its own success. The objective was to evaluate an epoxy paint used for pavement markings. The paint was believed to be tremendously durable. The paint was made of two compounds that were mixed at application, along with glass beads. First, the equipment spraying the paint malfunctioned, so only one of the compounds could be sprayed for some of the test. By itself, this paint turned black, an undesirable color for traffic markings. During the otherwise correct painting of another section of roadway, the equipment did not move

in a straight line, and this paint had to be taken up as well. Finally, a third batch of paint was applied correctly and gave good service. The difficulty in sandblasting off the two unwanted sections of pavement markings led the lead investigator to note that the paint, though expensive, "may have some possibilities." However, the contractor for the Iowa DOT refused to apply more paint, perhaps due to the difficulty experienced with the first two efforts. Another contractor was found after a two-year delay.

Chemcrete, a chemical treatment for asphalt, was experimentally used on roads in Story County, with approval coming in 1980 (HR-226). The Texas-manufactured Chemcrete was supposed to improve the stability of asphalt and prevent cracking. By June 1982 the Iowa DOT's Office of Materials noted that the material was riddled with large cracks. The final report in April 1984 minced no words. The report indicated that the additive was merely unsatisfactory in one case but actively detrimental in the other. In both cases it would have to be removed and the road rebuilt.

The electronically supplemented stop sign proved somewhat less successful than hoped.

Conclusion

Throughout its history, the Iowa DOT (and its predecessor, the Iowa State Highway Commission) has placed great emphasis on practical research and the improvement of the local road system. The creation of the Iowa Highway Research Board in 1949 may best be understood as symbolic of that dual emphasis.

From its first meeting in 1950, the Board has undertaken innovative work on projects designed to improve the efficiency of both the secondary and the primary road systems. Many of those projects have received national attention, and many resulted in methods that were developed into standard practices. Some projects, like the design and construction of the first welded aluminum girder bridge in the United States, were overshadowed by subsequent events and did not lead to widespread imitation. Other work, such as the partial removal and repair of bridge decks, was quickly and generally adopted by highway departments across the country.

After 50 years of sponsoring important highway research, the Iowa Highway Research Board approaches the twenty-first century with a record of achievement that warrants optimism. Certainly the Board will continue to serve both the citizens of Iowa and the engineering profession with dedication and good judgment.

Iowa Highway Research Board meeting in 1999

Note on Sources

Comparatively little historical investigation has been undertaken on the subject of highway research at either the federal or state level. Bruce Seely considered the work of the U.S. Bureau of Public Roads between the world wars in a 1984 issue of Technology and Culture.[2] In 1997 Leo Landis examined the role of highway research in the development of the Iowa State Highway Commission in his book Building Better Roads: Iowa's Contribution to Highway Engineering 1904–1974.[3] Considerable opportunities exist in the field for further research.

Within the Iowa Department of Transportation, a plethora of primary source records is available for scholars. For this work, the Iowa Highway Research Board minutes from 1950 to 1999 were carefully examined and, unless otherwise noted, provided the quotes in this work. The annual reports on research made to the governor and the general assembly were also carefully examined. Early issues of the Iowa State Highway Commission employee bulletin provided considerable information about the career of Mark Morris during his tenure as secretary to the Iowa Highway Research Board. Each research project undertaken gave rise to one or more files, and each project undertaken was also described in the minutes and in the annual reports of the Board. Especially significant projects were likely to be reviewed at least briefly in the annual reports of the Iowa State Highway Commission, at least into the early 1970s; such notices provided insight into the dissemination of research to the public. All of these sources were examined.

Scholars pursuing the subject further may wish to consider the press coverage or public attention given to research over the last 50 years; such a study was beyond the scope of the present work but would be well worthwhile.

[1]Ashton, Edward. Letter to Mark Morris, Oct. 3, 1957. As quoted in Fraser, Clayton B., and Roberts, John J., *Historic American Engineering Record: 86th Street overpass, Northwest 86th Street and Interstate 35/80, Des Moines, Photographs, Historical and Descriptive Data*, Denver: Historic American Engineering Record, National Park Service, Rocky Mountain Regional Office (1993).

[2]Seely, Bruce. "The Scientific Mystique in Engineering: Highway Research at the Bureau of Public Roads, 1918-1940," *Technology and Culture*, vol. 25, no. 4 (October, 1984).

[3]Landis, Leo. *Building Better Roads: Iowa's Contribution to Highway Engineering 1904-1974*. Ames, Iowa: Center for Transportation Research and Education, Iowa State University (1997).

Appendix A

Chair and Vice Chair of the Iowa Highway Research Board

Year	Chair	Vice Chair
1950	W. E. Jones	Bert Myers
1951	W. E. Jones	Bert Myers
1952	R. E. Robertson	Bert Myers
1953	J. F. Downie Smith	W. H. Root
1954	W. H. Root (d. April)	R. H. Justen
	R. H. Justen	Bert Myers
1955	R. H. Justen	Bert Myers
1956	Bert Myers	J. F. Arthurs
1957	J. F. Arthurs	R. C. Boyd
1958	R. C. Boyd	M. Rubek
1959	M. Rubek	J. Mors
1960	A.F. Faul	J. Mors
1961	A.W. Melloh	P. J. Mahoney
1962	P. J. Mahoney	G. E. Hales
1963	J. L. Holdefer	E. G. Clayton
1964	G. R. Town	T. E. McElherne
1965	J.F. Berry	T. E. McElherne
1966	T. E. McElherne	H. S. Smith
1967	H. S. Smith	A. L. Heeren
	A. L. Heeren (May)	
1968	D. Canney	R. H. Given
1969	R. H. Given	H. Rouse
1970	H. Rouse	W. G. Davison
1971	W. G. Davison	A. O. Chantland
1972	A. O. Chantland	D. E. McLean
1973	D. E. McLean	D. R. Boylan
1974	D. R. Boylan	W. H. Jorgenrud
1975	R. Murdock	J. White
1976	J. White	W. L. Morris
1977	R. H. Given	R. G. Hering
1978	R. G. Hering	E. Schornhorst
1979	E. Schornhorst	W. W. Amundson
1980	W. W. Amundson	G. Calvert
1981	G. Calvert	D. R. Boylan
1982	D. R. Boylan	D. D. Linnan
1983	D. D. Linnan	R. Kirchner
1984	R. Kirchner	D. Anderson
1985	D. A. Anderson	R. G. Hering
1986	R. G. Hering	R. Gumbert
1987	R. Gumbert	R. Holland
1988	R. Holland	G. Anderson
1989	G. Anderson	D. Kao
1990	D. Kao	R. Krieg
1991	R. Krieg	L. Stevens

Year	Chair	Vice Chair
1992	L. Stevens	G. Sisson
1993	G. Sisson	J. Odgaard
1994	J. Odgaard	M. Nahra
1995	M. Nahra	P. Wiegand
1996	P. Wiegand	G. Sisson
1997	G. Sisson	L. Griemann
1998	L. Greimann	J. B. Morrissey
1999	T. Stoner	T. Myers

Appendix B

Members and Alternates of the Iowa Highway Research Board 1950–1999

Note: The following list of members and alternate members of the Iowa Highway Research Board has been compiled from membership lists kept by the secretary of the Board. Where a county or city is listed, the member was the county or city engineer. Where ISHC or Iowa DOT is listed, the member was an employee of the Iowa State Highway Commission or the Iowa Department of Transportation, respectively. Where ISC or ISU is listed, the member was an employee of Iowa State College or Iowa State University, respectively. Where SUI or U of I is listed, the member was an employee of the State University of Iowa or the University of Iowa, respectively. V. R. Bennion, an employee of the United States Geological Survey, served for many years as an alternate appointed by the State University of Iowa.

S. B. Agnew, Madison Co., alt., 1966–1968
F. W. Akers, Calhoun Co., alt., 1961; member, 1963–1966
S. Akes, Guthrie Co., alt., 1984; member, 1985
W. W. Amundson, City of Sioux City, alt., 1975–1976; member, 1977–1982
C. B. Anderson, ISHC, alt., 1955–1967
D. A. Anderson, Iowa DOT, member, 1977–1992
G. W. Anderson, Iowa DOT, member, 1987–1990
J. Anderson, City of Marshalltown, alt., 1967–1974
W. L. Anderson, OíBrien Co., alt., 1950–1951; member, 1953–1955
D. Anthoney, Boone Co., alt., 1987; member, 1988–1990
J. F. Arthurs, Jr., Marshall Co., alt., 1953–1954; member, 1955–1957
C. W. Baldwin, Black Hawk Co., alt., 1950–1955; member, 1956–1957
W. H. Behrens, Linn Co., alt., 1956–1957; member, 1958–1959
E. Beisell, Jones Co., alt., 1971–1972
W. R. Bennett, Cherokee Co., alt., 1968–1970; member, 1971–1974
V. R. Bennion, USGS, alt., 1950–1964
J. F. Berry, Worth Co., alt., 1960–1962; member, 1963–1965
R. Betterton, Greene Co., member, 1979–1981
G. Bishop, Jefferson Co., alt., 1994
F. Bloomfield, ISHC, alt., 1965–1979; member, 1980–1982
R. I. Bortle, ISHC, alt., 1970–1972, 1989–1990; member, 1973–1975; 1991–1992
C. C. Bowman, Jackson Co., alt., 1962–1964; member, 1965–1967
R. C. Boyd, ISHC, member, 1954–1958
D. R. Boylan, ISU, alt., 1959–1970; member, 1971–1985
R. L. Brice, Commissioner, ISHC, 1958–1960
B. C. Brown, Iowa DOT, alt., 1985–1992; member, 1993–1996
J. Bump, Iowa DOT, alt., 1985–1987; member, 1988–1990
M. Burr, Iowa DOT, alt., 1993–1995
J. G. Butter, ISHC, alt., 1960.
C. Cabalka, Jasper Co., alt., 1973–1975; member, 1976–1978
E. T. Cackler, Iowa DOT, alt., 1993
J. C. Calhoun, Madison Co., alt., 1975; member, 1976
G. Calvert, Iowa DOT, member, 1978–1986
D. Campbell, Iowa DOT, alt., 1976

F. Campbell, Clay Co., alt., 1953–1955; member, 1956–1958
D. Canney, City of Cedar Rapids, member, 1966–1977
C. Caspars, City of Urbandale, alt., 1971–1974
O. Chantland, City of Ames, member, 1965–1974
C. Christensen, Fremont Co., alt., 1982–1983
J. Christensen, Page Co., alt., 1987–1990; member, 1991–1993
V. L. Clark, Decatur Co., alt., 1973–1974; member, 1975–1977
L. M. Clausen, ISHC, alt., 1954; member, 1954–1961
E. G. Clayton, Scott Co., alt., 1960–1961; member, 1962–1964
L. E. Clayton, Jefferson Co., alt., 1953; member, 1954
L. S. Csanyi, ISC, alt., 1950–1957; member, 1958
L. W. Croft, Dallas Co., alt., 1950–1951, member, 1952–1954
J. R. Daugherty, Muscatine Co., member, 1950–1951
W. G. Davison, Cerro Gordo Co., alt., 1966–1968; member, 1969–1972
F. M. Dawson, SUI, member, 1950–1960
S. De Vries, Jackson Co., alt., 1989–1991; member, 1992–1996
R. De Wys, Scott Co., alt., 1983–1985; member, 1986–1988
J. F. Downie Smith, ISC, member, 1950–1957
R. W. Dutton, Marion Co., member, 1958–1960
P. Dvorak, Grundy Co., alt., 1979–1981; member, 1982
D. East, Iowa DOT, alt., 1991–1995
C. A. Elliott, Greene Co., member, 1950–1951
G. R. Elliott, Buchanan Co., alt., 1958–1959; member, 1960–1961
J. Erickson, City of Mason City, alt., 1989–1990; member, 1991
A. Estvold, Montgomery Co., alt., 1997–1998
F. Farmer, City of Fort Dodge, alt., 1995–1999
A. F. Faul, ISHC, member, 1960–1963
D. Finch, Fayette Co., alt., 195–1959; member, 1960–1962
R. J. Fitchner, Grundy Co., alt., 1976–1978
R. J. Fitchner, Marshall Co., alt., 1983–1986, 1991–1993; member, 1994–1996
H. D. Floyd, Plymouth Co., member, 1965–1967
J. L. Franklin, City of West Des Moines, member, 1965
F. L. Freeman, Sac Co., alt., 1960–1961; member, 1962–1964
O. K. Frink, Polk Co., alt., 1958–1960M. Gardner, Johnson Co., alt., 1998–1999
J. George, Dallas Co., alt., 1996–1997; member, 1999
R. H. Given, ISHC, alt., 1962–1964; member, 1965–1979
W. A. Groskurth, Mitchell Co., alt., 1975–1977; member, 1978–1980
J. S. Goode, Monroe Co., alt., 1995; member, 1996–1998
L. F. Greimann, ISU, alt., 1993–1995; member, 1996–1999
G. L. Gronvold, Jefferson Co., alt., 1978–1979
N. Guess, City of Newton, alt., 1992–1994; member, 1995–1997
R. Gumbert, Tama Co., alt., 1982; member, 1983–1987
C. E. Hales, Lee Co., member, 1961–1963
M. O. Hansen, Poweshiek Co., alt., 1970–1972; member, 1973–1975
G. E. Hanzlik, Delaware Co., alt., 1967; member, 1968–1970
G. R. Hardy, Dallas Co., member, 1970–1972
W. G. Harrington, Linn Co., alt., 1968–1970; member, 1971–1974
R. L. Haylock, Butler Co., alt., 1972–1974, 1984–1985; member, 1975–1977, 1986–1989
G. S. Held, Guthrie Co., alt., 1950–1953; member, 1954–1956
A. L. Heeren, Winnebago Co., alt., 1963–1965; member, 1966–1968

R. C. Henely, ISHC, alt., 1977–1978; member, 1970–1972; 1979–1981
R. G. Hering, U of I, member, 1973–1992
H. E. Hickthier, Floyd Co., member, 1957–1959
W. Hinderman, Louisa Co., alt., 1950–1951, 1958, member, 1952–1953
A. W. Hinderman, Washington Co., alt., 1959–1960
J. F. Hoag, ISHC, alt., 1957–1959
S. J. Holcomb, Grundy Co., alt., 1988–1990; member, 1991–1993
J. L. Holdefer, ISHC, member, 1962–1964
R. Holland, City of Bettendorf, alt., 1979–1982; member, 1983–1988
L. N. Hoppock, Page Co., member, 1963–1965
J. W. Howe, SUI, alt., 1950–1961
R. G. Huber, Washington Co., alt., 1965–1968; member, 1969–1972
C. L. Huisman, Iowa DOT, member, 1980–1984
F. W. Inghram, Des Moines Co., alt., 1961–1963; member, 1964–1965
O. Ives, Monona Co., member, 1984–1988
M. Johnson, Wapello Co., alt., 1984–1986
W. E. Jones, ISHC, member, 1950–1953
W. H. Jorgenrud, Bremer Co. , alt., 1969–1972; member, 1972–1974
N. Jorgenson, Franklin Co., alt., 1981–1983; member, 1984–1985
D. Julius, Sioux Co., alt., 1998–1999
R. H. Justen, Johnson Co., alt., 1951, member, 1951–1955
H. Kane, U of I., alt., 1972–1974, 1980–1984
D. Kao, ISU, 1989–1994
J. F. Kennedy, SUI, alt., 1967–1969
R. Kirchner, City of Fort Dodge, alt., 1978–1980; member, 1981–1984
S. J. Klassen, Des Moines Co., alt., 1987–1989
R. Knoke, City of Burlington, alt., 1997–1999
N. Konrady, Lucas Co., alt., 1980; member, 1981–1983
R. Krauel, City of Carroll, alt., 1989–1996; member, 1997–1999
R. A. Krieg, Buchanan Co., alt., 1986–1988; member, 1989–1991
L. Laartz, Chickasaw Co., alt., 1990–1992; member, 1993–1995
M. Larson, Henry Co., alt., 1954, 1960–1961; member, 1955–1957
D. D. Linnan, Buena Vista Co., alt., 1977–1979; member, 1980–1983
D. Little, Iowa DOT, member, 1999
R. F. Lundy, Commissioner, ISHC, member, 1958–1959
R. M. Love, Pocahontas Co., alt., 1956; member, 1957–1961
D. J. Lynam, Adair Co., alt., 1977–1981; member, 1982–1984
P. J. Mahoney, Pottowattamie Co., alt., 1957–1959; member, 1960–1962
C. Marker, Fremont Co., alt., 1999
L. Mattusch, Clinton Co., alt., 1979; member, 1980–1982
G. Mauer, Grundy Co., alt., 1994–1996; member, 1997–1999
T. Maze, ISU, alt., 1996–1999
M. McClain, Appanoose Co., member, 1987–1992
T. E. McElherne, ISHC, member, 1962–1964; alt., 1968–1982
D. E. McLean, ISHC, member, 1968–1977
K. M. Meeks, Iowa DOT, alt., 1991–1992; member1993–1995
H. Melloh, SUI, member, 1961–1965
R. E. Merrill, ISHC, alt., 1959–1966
R. Michaelis, Carroll Co., alt., 1980–1984
P. A. Michel, Montgomery Co., member, 1950–1953

D. E. Miller, Fremont Co., alt., 1985–1986
W. A. Moellering, Fayette Co., alt., 1978–1980; member, 1981–1983
F. Moore, City of Cedar Falls, alt., 1977–1978
W. L. Morris, ISHC, alt., 1973–1975; member, 1976
J. B. Morrissey, Madison Co., alt., 1991–1996; member, 1997–1999
J. C. Mors, Webster Co., alt., 1955–1957; member, 1958–1960
R. L. Murdock, Audubon Co., member, 1969
R. Murdock, Buchanan Co., alt., 1972–1974; member, 1975
B. Myers, ISHC, member, 1950–1959
T. Myers, City of Creston, member, 1998–1999
M. Nahra, Cedar Co., alt., 1992–1993; member, 1994–1997
C. L. Narotam, Iowa DOT, member, 1997–1999
T. E. Nelson, Muscatine Co., alt., 1969–1972; member, 1973–1974
E. Niebuhr, City of Clinton, alt., 1975–1977; member, 1978–1980
W. Nixon, U of I, alt., 1993–1999
M. H. Noonan, Cass Co., alt., 1972; member, 1973–1974
A. J. Odgaard, U of I, 1993–1999
C. E. Olson, Poweshiek Co., member, 1961–1962
D.Osipowicz, Lee Co., alt., 1998; member, 1999
G. F. Parkin, U of I., alt., 1991–1992
R. F. Percival, Iowa DOT, alt., 1979–1981; member, 1982–1984
C. Pestonik, Iowa DOT, alt., 1983–1984
J. Petermeier, Benton Co., alt., 1980–1982; member, 1983–1985
L. G. Petersma, Van Buren Co., alt., 1976–1977; member, 1978–1980
P. W. Peterson, ISU, alt., 1972–1988
R. Ransom, City of Cedar Rapids, alt., 1985–1987; member, 1988–1990
R. A. Rawlings, Monona Co., alt., 1962–1964
R. Reinhart, Pocahontas Co., alt., 1971–1974; member, 1975–1976
B. Ridenour, Delaware Co., alt., 1997; member, 1998–1999
E. Rike, Adams Co., member, 1987–1990
Kwan Rim, U of I, alt., 1975–1979
R. E. Robertson, Cerro Gordo Co., member, 1950–1954
J. T. Robeson, Wayne Co., alt., 1955–1957
T. G. Rohe, Plymouth Co., alt., 1985–1988; member, 1989–1991
W. H. Root, ISHC, member, 1950–1954
H. Rouse, SUI, member, 1967–1972
M. A. Rubek, Ringgold Co., alt., 1954–1956; member, 1957–1959
W. Sanders, ISU, alt., 1989–1994; member, 1995
R. R. Sapp, Union Co., alt., 1963–1965; member, 1966–1968
J. H. Scheel, alt., Black Hawk Co., 1965–1966
R. O. Schiek, Kossuth Co., alt., 1986–1989; member, 1990–1992
L. J. Schiltz, Dubuque Co., member, 1950
C. Schmadeke, City of Iowa City, alt., 1983–1988
F. C. Schneider, ISHC, alt., 1954–1956
F. Schnoor, Boone Co., alt., 1967–1969; member, 1970–1972
J. L. Schnoor, U of I, alt., 1985–1990
D. Schoberlein, Humboldt Co., alt., 1954–1956
E. Schornhorst, Buena Vista Co., alt., 1959
E. Schornhorst, Shelby Co., alt., 1976; member, 1977–1981
W. J. Schreiner, City of Ankeny, alt, 1981–1984; member, 1985–1987

W. L. Schultz, Guthrie Co., alt., 1973–1974; member, 1975
R. F. Sears, Monroe Co., alt., 1975
D. R. Shaw, Ida Co., member, 1977–1979
R. Simmering, Muscatine Co., alt., 1981–1983; member, 1984–1986
G. F. Sisson, Iowa DOT, alt., 1985–1990; member, 1991–1998
R. T. Skrinde, U of I, alt., 1970–1971
F. A. Smiley, ISHC, alt., 1967–1969
D. L. Smith, Delaware Co., alt., 1975; member, 1976–1979
H.S. Smith, SUI, alt., 1965; member, 1966
K. F. Smith, Louisa Co., alt., 1964–1965; member, 1965–1968
W. D. Smith, Hamilton Co., alt., 1963–1966; member, 1967–1969
L. Smithson, Iowa DOT, member, 1996–1999
J. Smythe, Iowa DOT, alt, 1995–1996
T. Snyder, Osceola Co., alt., 1989–1991; member, 1992–1994
V. R. Snyder, Iowa DOT, alt., 1982–1984; member, 1959–1961, 1985–1987
L. Stevens, City of Oskaloosa, alt., 1988; member, 1989–1994
J. L. Stober, Chickasaw Co., alt., 1950–1953
T. Stoner, Harrison Co., alt., 1995–1997; member, 1998–1999
E. D. Tice, Appanoose Co., alt., 1990–1992; member, 1993–1995
G. R. Town, ISC, alt., 1950–1956; member, 1959–1970
W. D. Upmeyer, Jackson Co., 1976–1978
C. Van Buskirk, Keokuk Co., alt., 1999
D. R. Waid, Van Buren Co., alt., 1993–1996
F. Walker, Iowa DOT, alt., 1996–1998
K. M. Wallace, Lyon Co., alt., 1965–1967; member, 1968–1970
R. J. Wallace, Buchanan Co., alt., 1950; member, 1951
M. Walton, Iowa DOT, alt., 1996–1999
C. K. Weber, Mills Co., alt., 1969
J. Weber, Clayton Co., alt., 1999
P. Weigand, City of Ames, alt., 1991; member, 1992–1996
W. Weiss, Greene Co., alt., 1997–1999
T. Welch, Iowa DOT, alt., 1999
J. White, City of Dubuque, member, 1975–1976
K. White, Sac Co., alt., 1992–1994; member, 1995–1997
W. W. Wickham, ISHC, member, 1964–1969
H. D. Wight, Crawford Co., alt., 1975–1976
R. J. Will, Franklin Co., alt., 1993–1995; member, 1996–1998
J. Witt, Cerro Gordo Co., alt., 1996–1998; member, 1999
E. Winkle, Osceola Co., member, 1950–1951
R. A. Younie, Iowa DOT, alt., 1997–1999
O. W. Zack, Butler Co., alt., 1954; member, 1954–1956

Appendix C

Iowa Highway Board Research Projects 1949–1999

Dates indicate the years in which projects were initiated.

Year	No.	Title
1950	1.	Investigation of Loess and Glacial Till Materials of Iowa
	2.	Analysis of Flood Frequencies and Flood Magnitudes
	3.	Determination of Flood Discharge Characteristics of Small Drainage Areas
	4.	Thickness of Stabilized Aggregate Base for Use with Bituminous Surface
	5.	Elimination of Long Bridges on Streams with Small Drainage Areas
	6.	Erosion Protection for Highway Fills
	7.	Accelerated Testing of Highway Pavements and Bases
	8.	Origin and Destination Traffic Surveys
	9.	Thickness of Concrete Pavements for Light Traffic Roads
	10.	Durability of Portland Cement Concrete
	11.	Investigation of Sources of Highway Materials in Southwest Iowa
	12.	Distribution of Loads in Beam and Slab Bridges
1951	13.	Extent and Nature of Rural Road Usage
	14.	Lateral Pressures on Retaining Walls
	15.	Limestones for Concrete Aggregates
	16.	Sediment Transportation in Conduits
	17.	Low Cost Surfacing for Secondary Roads
	18.	Low Cost Asphalt Surface Construction
	19.	Use of Sand as a Highway Material
	20.	An Investigation of Methods of Treatment of Loess, Fine Sands, and Limestone Dust with Various Liquid Binders
1952	21.	Use of Shale as Highway Material
	22.	Fertilizer Response on Highway Cuts and Fills
	23.	Hydraulic Design of Highway Culverts
	24.	Field Observation on Scour around Bridge Piers and Abutments
	25.	Prestressed Concrete Highway Bridges
	26.	Evaporative Drying of Subgrade Soils
1953	27.	Movement of Moisture through Soil
	28.	Size of Aggregate for Traffic Bound Roadway Surfaces
	29.	Compilation of Drainage Areas in Iowa
	30.	Scour in Stream Beds at Highway River Crossings
1954	31.	Structural Behavior of Bridge Abutment Wing Walls
	32.	Oils and Tars from Iowa Shales
	33.	Characteristics of Chemically Treated Roadway Surfaces
	34.	Thin Concrete Resurfacing
1955	35.	Service Tests of Traffic Marking Paints
	36.	Prestressed Concrete Beams
	37.	Methods of Controlling Erosion of Newly-Seeded Highway Backslopes in Iowa
	38.	Compilation and Automation of Iowa Highway Laws

1956	39.	Analysis of Ralston Creek Basin Runoff Records
	40.	Steam Curing of Portland Cement Concrete at Atmospheric Pressure
	41.	Determination of New Formula for Bearing Value of Piles
	42.	Dynamic Tests of I-Beam Bridges
	43.	Fatigue Strength of Rolled Steel Beams with Welded Cover Plates
	44.	Field Tests of Treatment of Fine Materials
	45.	Study of Highway Laws
	46.	Compilation of Iowa Drainage Laws
	47.	Roadside Seeding with Hydraulic Seeders
	48.	X-Ray Diffraction Analysis of Highway Materials
	49.	Stream Profiles for Given Frequencies of Flow
	50.	Sufficiency Ratings of Marion County Secondary Roads
1957	51.	Use of Aluminum in Highway Bridges
	52.	Experimental Sections in Primary Road Project F-772(7)—Jasper Co.
	53.	Serviceability of Bituminous Paving Mixtures
	54.	Use of Foamed Asphalt in Soil Stabilization
	55.	Shoulder Stabilization Section in Primary Road Project F-772(7)—Jasper County
	56.	Experimental Road in Carroll County Farm-to-Market Road Project SN-821
	57.	Experimental Road in Carroll County Secondary Road Project TP-l-57
	58.	Experimental Road in Audubon County Farm-to-Market Road Project SN-242
	59.	Use of Lignins for Dust Control
	60.	Secondary Road Administration in Iowa
	61.	Distribution of Loads in Beam and Slab Bridge Floors
	62.	Loss of Prestress in Pretensioned Prestressed Concrete Beams
1958	63.	Foamed Asphalt in Slurry Seal Coats
	64.	Prevention of Erosion on Highway Backslopes
1959	65.	Study of Rock Materials in Southwestern Iowa
	66.	Application of Slurry Seal Coats in Hancock County
	67.	Dynamics of Highway Bridges
	68.	Soil Stabilization in Experimental Road in Webster County
	69.	A Study of Iowa Aggregate for Foamed Asphalt Slurry Seals
	70.	Study of Properties of Carbonate Rocks in Iowa
	71.	Flood Information at Selected Bridge Sites
1960	72.	Linn County Slurry Seal
	73.	Prestressed Steel Beams for Highway Bridges
	74.	Use of Prestressed Steel Beams in Highway Bridges
1961	75.	Experimental Soil Cement Construction
	76.	Curb Removal Study
	77.	Commission Vehicles
	78.	Carbonate Mineralogy and Stratigraphy of Rocks in Iowa
	79.	The Effect of Fillers on the Properties of Asphaltic Concrete Mixes
	80.	Application of the Calderon Test to Iowa Asphaltic Concrete Mixes
	81.	Physical Methods of Testing Soils and Stabilized Soil Mixtures
	82.	Soil Stabilization with Cement and Lime
	83.	Soil Stabilization with Chemicals
	84.	Cement Treated Crushed Stone Base—Fremont County

1962	85.	The Relative Strength of Various Base Course Materials
	86.	Relationship of Carbonate Aggregate to Serviceability of Portland Cement Concrete
	87.	Pavement Resurfacing—Special Problems
1963	88.	Soil Consistency Limits and Moisture Tensions
	89.	Stream Stabilization Structures
	90.	Soil Stabilization—Field Projects
	91.	Experimental Construction—Hamilton County
	92.	Use of Sucrose and Dextrose Portland Cement Concrete Paving
	93.	Surface Distortion of Flexible Pavements
	94.	Residual Stresses and Fatigue Behavior of Welded Structural Members
	95.	Repair and Protection of Concrete Bridge Superstructures
	96.	Control of Erosion on Highway Backslopes during the Seeding Period
	97.	Chemical Stabilization and Physicochemical Properties of Soils
	98	Snow Removal and Ice Control in Urban Areas
	99.	Factors Influencing Stability of Granular Base Course Mixes
1964	100.	Service Correlation of the Traffic Simulator
	101.	Field Testing of Asphaltic Concrete Mixes
	102.	Electronic Weigh-in-Motion Scales
	103.	Use of Nuclear Energy in the Highway Industry
	104.	Camber Measurements on Prestressed Concrete Bridge Beams
	105.	A Study of the Effect of Elastomeric Bearings on the Dynamics of Highway Bridges
	106	X-Ray Diffraction Studies of Soil and Soil Stabilizers
	107.	Behavior of Asphalt in the Production of Asphaltic Concrete
	108.	Development of Seedings for Highway Medians
	109.	Programmed Instruction in Plan Reading
	110.	Compositional and Mechanical Properties of Carbonate Rocks
1965	111.	X-Ray Diffraction and Crystal Chemistry of Highway Materials
	112.	Correlation of Bedrock in Southern Iowa
	113.	Lane-Wells Road Logger
	114.	Seismic-Wave Velocity as a Means of In-Place Density Measurement
	115.	NUMBER NOT USED
	116.	NUMBER NOT USED
	117.	Rapid Bearing Tests Using a Spherical Penetration Device
	118.	Carbonate Aggregate for Portland Cement Concrete
	119.	Scale Effects in Model Tests of Rock-protected Structures
	120.	Concrete Popouts
	121.	Skid Test Vehicle
1966	122.	Concrete Pavement Studies
	123.	Favorable and Unfavorable Effects of Non-Tensioned Steel in Prestressed Concrete Beams
	124.	Development of a Laboratory Durability Test for Asphalt
	125.	Joints and Joint Seals in Portland Cement Concrete
	126.	A Mechanistic Explanation of the Physical Properties of Undisturbed Loess
	127.	Effects of Absorption of Asphalt by Aggregate on Properties of Asphalt and Asphalt Mixes
	128.	X-Ray Diffraction Analysis of Highway Materials
	129.	A Uniform Accounting System for County Road Departments

1967	130.	Evaluation of the Safety Potential of County Roads
	131.	Granular Base Materials for Flexible Pavements
	132.	Evaluation of the Use and Effectiveness of Information Centers on Interstate 80
	133.	Studies of Herbaceous Plant Species on Highway Rights-of-Way
	134.	Development of a Frost and Ice Detection System for Highway Bridges
	135.	Stresses in Bases and Subgrades
	136.	Creep and Shrinkage Properties of Lightweight Aggregate Concretes Used in Iowa
	137.	Time-Dependent Camber and Deflection of Non-Composite and Composite Lightweight Prestressed Concrete Beams
1968	138.	Optimum Level of Enforcement of Regulations Governing the Size and Weight of Motor Vehicles Operated on Iowa Highways
	139.	Criteria for the Evaluation and Disposition of Low-Traffic County Secondary Roads
	140.	Collection and Analysis of Stream Flow and Related Hydraulic Data for Design of Highway Bridges and Culverts
	141.	Deterioration of Portland Cement Concrete Pavements
	142.	Absorption of Asphalt by Aggregate
	143.	Development of a Computer Program for Roadway Profile Adjustment
1969	144.	Consolidation of Loess
	145.	Salvaging and Re-Use of Plant Materials
	146.	Preliminary Studies of Remedial Measures of the Prevention of Bridge Deck Deterioration
	147.	Guidelines for the Inclusion of Left Turn Lanes at Rural Highway Intersection
	148.	Investigation of Pavement Wear in Relation to the Use of Studded Tires
1970	149.	Preliminary Archaeological Investigation along Proposed Highway Right-of-Way
	150.	Organization and Coordination of the Highway Planning Function in Iowa
	151.	Surface Improvement and Dust Palliation of Unpaved Secondary Roads and Streets
	152.	Measurement of Pavement Surface Variations
	153.	Investigation of the Nature and Hazards of Asphalt Plant Related Possible Pollution Problems
	154.	Investigation of Highway Lighting
	155.	Soil Erosion for Secondary Roads
	156.	Detection of Steel Corrosion in Bridge Decks Reinforced Concrete Pavement
1971	157.	Evaluation of Gap-Graded Asphalt Concrete Mixtures
	158.	Prevention of Reflection Cracking in Asphalt Overlays
	159.	A Study of Roadside Vegetation Control
	160.	Feasibility Study of Dynamic Overload and Ultimate Load Tests of a Full-Scale Highway Bridge

1972	161.	Insurance Needs of Iowa County Highway Departments (Cancelled)
	162.	Variation of the Coefficient of Drag with Variation in Both Reynolds Number and Corner Radius for 8-, 12- and 16-sided Polygonal Cylinders
	163.	HELP—Highway Emergency Long-Distance Phone
	164.	A Computer Application Study Directed to Development of an Improved Hydrologic Design Method for Culverts
	165.	Experimental Steel Fiber Reinforced Concrete Overlay
1973	166.	Freeway Operation Analysis of 1-80, 1-29 Interchange
	167.	Maintenance of Pavement Skid Resistance
	168.	Skid Resistance of Concrete Pavements
1974	169.	Ultimate Load Behavior of Full-Scale Highway Truss Bridges
	170.	Maintenance of Pavement Skid Resistance
	171.	Evaluation of Crushed Limestone Rock for Soil Stabilization and Pollution Control on Disturbed Areas of Iowa Highways
	172.	Experimental Use of Thermoplastic Paint for Traffic Lane Marking
	173.	A Computer Based Information System for County Equipment Cost Records
	174.	Visibility and Relative Motion of Iowa State Highway Commission Snow Plows
1975	175.	Experimental Macadam Stone Base
	176.	Recycled Asphalt Pavement
	177.	Concrete Bridge Deck Repairs Using Injected Epoxy Resin
	178.	Pavement Deflection Study (Road Rater)
	179.	Bridge Deck Delamination Study
1976	180.	An Evaluation of an Epoxy Pavement Marking System
	181.	The Evaluation of Macadam Stone Shoulders
	182.	An Evaluation of Cover Aggregate Stripping Characteristics
	183.	Fatigue Behavior of High Air Content Concrete
	184.	Determination of Rumble Strip Effectiveness
	185.	Laboratory Study of Slurry Seals
	186.	Evaluation of Changes in Productivity Resulting from Removal of Soil for Highway Construction
	187.	Development of a Minicomputer Controlled Frost, Ice and Snow Detector for Bridge Hazard Monitoring
1977	188.	Evaluation of Air Pollution Control Devices for Asphalt Pavement Recycling Operations
	189.	A Study of the Spergen Formation of Southeastern Iowa
	190.	Portable School Stop Signs and Other Non-Uniform School Stop Control Devices
	191.	Bonded, Thin-Lift, Non-Reinforced Portland Cement Concrete Resurfacing
	192.	An Evaluation of Dense Bridge Floor Concrete
	193.	Field Application of an Inexpensive Dust Alleviation product
	194.	Mission-Oriented Dust Control and Surface Improvement Processes for Unpaved Roads
	195.	Field Performance and Evaluation of Slurry Seal Coats
	196.	Dust Control Using an Asphalt Emulsion
	197.	Fatigue Behavior of High Air Content Concrete—Phase II
	198.	Preliminary Archaeological Investigation along Proposed Highway Right-of-Way

1978	199.	Upgrading Asphalt Surface Friction by Aggregate Sprinkle Treatments
	200.	Fly Ash in Portland Cement Pavement—Monona County
	201.	Fly Ash in PC Pavement—Woodbury County
	202.	Wind Tunnel Analysis to Determine the Effect of Adjustment in the Adjacent Topography on Drifting Snow at Highway Grade Separations
	203.	Joint Sealing with Various Sealants
	204.	Safer Construction and Maintenance Practices to Minimize Potential Liability by Counties from Highway Accidents
	205.	Effects of Special Aggregate on Bridge Deck Overlay Frictional Properties
	206.	Cement Produced from Fly Ash and Lime
	207.	Feasibility of Wind-Powered Aeration of Rest Area Lagoons
1979	208.	Alternative Methods of Stabilizing the Degrading Stream Channels in Western Iowa
	209.	Pavement Surface on Macadam Base—Adair County
	210.	The Effect of Deer Reflectors on Deer-Vehicle Accidents
	211.	Performance of Randomly-Oriented Fiber Reinforced Roadway Soils
	212.	Suitability of Treating Iowa's Marginal Aggregates and Soils by Foamix process
	213.	Improved Asphalt Surfaces and Asphalt Resurfacing Performance Through Crack Maintenance
	214.	Feasibility Study of Strengthening Existing Single Span Steel Beam Concrete Deck Bridges
	215.	Improvement of Longitudinal Joints in Asphalt Pavement
	216.	Asphalt Emulsion Bound Macadam
1980	217.	Reducing the Adverse Effects of Transverse Cracking
	218.	Liability and Traffic Control Considerations for Low Level Stream Crossings
	219.	Settlement at Culverts and Bridges
	220.	Protection of Structural Concrete Substructures
	221.	Construction and Maintenance Practices to Minimize the Potential Liability of Counties for Roads in Rural Subdivisions
	222.	Retardation of Reflection Cracking Using Stabilizing Additive 5990
	223.	Engineering Study for Maintenance of Iowa's Granular Surfaced Roads
	224.	Restoration of Frictional Characteristics on Older PCC Pavement
	225.	Characterization of Fly Ash for Use in Concrete
	226.	Iowa Research with Chem-Crete Bitumen
	227.	Piling Stresses in Bridges with Integral Abutments
1981	228.	Engineering Study—Automating Iowa's Speed Monitoring Program
	229.	Alternate Flexible Overlays
	230.	An Investigation of Signing Needs at Local Road Intersections
	231.	Special Surface Preparation Prior to Bituminous Overlays
	232.	Reducing the Problem of Transverse Cracking
	233.	Field Demonstration and Evaluation of Foamed Asphalt
	234.	Compilation of Iowa Highway Laws
	235.	Warrants for Rumble Strips on Rural Highways
	236.	Pottawattamie Co. Evaluation of Control Structures for Stabilizing Degrading Stream Channels

237. Shelby Co. Evaluation of Control Structures for Stabilizing Degrading Stream Channels
238. Strengthening Existing Single Span Steel Beam Concrete Deck Bridges
239. Engineering Study to Evaluate Secondary Bridges with Respect to Current Truck Length and Weight Laws
240. Systems to Control Corrosion in Concrete
241. Development of EDMI Calibration Baseline
242. Economics of Alternative Solutions to the Secondary Roadway Problem

1982

243. Production and Evaluation of Calcium Magnesium Acetate (CMA)
244. Detection of Concrete Delaminations by Infrared Thermography
245. Dynamic Deflections to Determine Roadway Support Ratings
246. Engineering Study—Reducing Sign Vandalism
247. Design Criteria for Low Water Crossings
248. Evaluation of a Mobile Rut Depth Device for the Pavement Management Program
249. Governor's Task Force on Iowa's Transportation Future
250. A Non-Destructive Method for Determining the Thickness of Sound Concrete on Older Pavements
251. Roadway Lighting on Secondary Roads in Iowa
252. Piling Stresses in Bridges With Integral Abutments—II
253. Experimental Use of Calcium Magnesium Acetate (CMA)
254. Highway/Railroad Grade Crossings—Identification and Signing

1983

255. Submerged Vanes for Flow Control and Bank Protection in Streams at Roads and Highways
256. Perception and Interpretation of Advance Warning Signs on County Roads
257. Field Demonstration of Foamed Asphalt—Muscatine County
258. Frost Action in Rocks and Concrete
259. Low Cost Fly Ash-Sand Stabilized Roadway
260. Optimization of Soil Stabilization with Type C Fly Ash
261. Modifications to Improve the Reliability of the Iowa DOT Frost Detector
262. Signing on Very Low Volume Rural Roads
263. Engineering Study to Redesign the 24-Foot Secondary Bridge Standards (An Engineering Study for Metrication of Secondary Bridge Standards)
264. Development of a Sufficiency Rating System for Secondary Roads
265. Evaluation of Public Road Administration and Maintenance Alternatives
266. X-Ray Analysis of Carbonate Aggregate to Predict Concrete Durability
267. Engineering Study—Development of Training Aids for Snow Removal on Iowa's Secondary Roads

1984

268. Evaluation of Magnitude and Frequency of Floods in Iowa
269. Data Acquisition and Computer Plotting of Delamtect Data
270. Development of Training Aids and Demonstration of Portland Cement Concrete Pavement Rehabilitation
271. Effects of Deicing Salt Compounds on Deterioration of PC Concrete
272. Development of a Conductometric Test for Frost Resistance of Concrete

1985	273.	Piling Stresses in Bridges with Integral Abutments—Phase 3
	274.	Construction and Evaluation of Submerged Vanes for Stream Control
	275.	Long Term Structural Movement
	276.	Transverse Joint Sealing with Improved Sealants
	277.	Cracking and Seating PCC Pavement Prior to Resurfacing to Retard Reflection Cracking
	278.	Beneficial Effects of Selected Additives on Asphalt Cement Mixes
	279.	Cracking and Seating PCC Pavement Prior to Resurfacing to Retard Reflective Cracking—Fremont County
	280.	An Engineering Study to Update the Box Culvert Standards (Metrication of Single and Double Box Culvert Standards)
	281.	Effects of Pavement Surface Texture on Noise and Friction Characteristics
	282.	A Low Cost Automatic Weight and Classification System
	283.	Pavement Texturing by Milling
	284.	Development of Multiplan Microcomputer Spreadsheets for County Hydraulic and Highway Engineering Computations
	285.	Measuring Discharge at Crest-Stage Gaging Stations Using Tracer-Dilution Methods
	286.	Development of a Rational Characterization Method for Iowa Fly Ash
	287.	Strengthening of Existing Continuous Composite Bridges
	288.	Field Evaluation of Bonded Concrete Resurfacing
	289.	Maintaining Iowa's Secondary Road Environment
1986	290.	Ice-Retardant Pavement
	291.	Performance of Nongrouted Thin, Bonded PCC overlays
	292.	Validation of Design Recommendations for Integral Abutment Piles
	293.	Pavement Instrumentation
	294.	Ammonium Phosphate/Fly Ash Road Base Construction
	295.	Field Measurement of Bridges for Long Term Structural Movement
	296.	ISU Technology Transfer
	297.	Development of an Economic Dust Palliative for Limestone Surfaced Secondary Roads
	298.	Correlation of Locally-Based Performance of Asphalts with Their Physicochemical Parameters
1987	299.	Control of Concrete Deterioration Due to Trace Compounds in Deicers
	300.	Iowa Development of Roller Compacted Concrete
	301.	Iowa Development of Roller Compacted Concrete—Mills County
	302.	Alternate Methods of Bridge Strengthening
	303.	Field Evaluation of Cold In-Place Recycling of Asphalt Concrete
	304.	Production of Acetic Acid for CMA Deicer
	305.	Development of an Expert System for Forecasting Frost on Bridges and Roadways in Iowa
	306.	Investigation of Uplift Failures in Flexible Pipe Culverts
	307.	Sediment Control in Bridge Waterways
1988	308.	Strengthening of an Existing Continuous Span Steel Beam-Concrete Deck Bridge by Post-Tensioning
	309.	An Investigation of Emulsion Stabilized Limestone Screenings
	310.	Composite Precast, Prestressed Concrete Bridge Slabs
	311.	Creep and Resilient Modulus Testing of Asphalt Mixtures
	312.	Low Cost Techniques of Base Stabilization—Dubuque Co.

313. Air Formed Arch Culvert Construction—Washington Co.
314. Air Formed Arch Culvert Construction—Crawford Co.
315. Iowa Development of Rubblized Concrete—Mills Co.
316. Maximized Utility of the Global Positioning System

1989

317. Evaluation of Edge Drains
318. Evaluation of Preformed Neoprene Joint Seals
319. Lateral Load Resistance of Diaphragms in Prestressed Concrete Girder Bridges
320. Constructability in the Bridge Design Process
321. Production of Acetic Acid by Fermentation with Propionibacteria
322. Estimating Design Flood Discharge for Iowa Using Drainage Basin and Channel Geometry Characteristics
323. Development of Evaluation, Rehabilitation and Strengthening Concepts for Low Volume Bridges
324. Construction Plan Reading Course Update
324A. (Metrication of the Self Taught Math and Plan Reading Course Material) (1994)
325. Thermoset Composite Concrete Reinforcement
326. The Development of More Cost Effective Paved County Roads Using Phased Construction

1990

327. Evaluation of Chemical Durability of Iowa Fly Ash Concretes
328. Engineering Study—Guardrail Attachment Details for Existing Bridges
329. Hydrodemolition Preparation for Dense Concrete Bridge Overlays
330. Evaluation of Recycled Rubber in Asphalt Concrete
330A. Asphalt Rubber Project—Plymouth Co.—FN-140-2(6)—21-75
330B. Asphalt Rubber Project—Black Hawk Co.—FN-21-6(6)—21-07
330C. Asphalt Rubber Project—Dubuque Co.—FN-l5l-5(34)—21-31
330D. Asphalt Rubber Project—Black Hawk Co.—FN-218-7(150)—21-07
331. Engineering Study—Skewed Tee Piers for Secondary Bridges
332. Design Methodology for Corrugated Metal Pipe Tiedowns: Phase I
333. Design Methodology for Post-Tensioning Strengthening of Continuous Span Bridges
334. Field Measurements of Plow Loads during Ice Removal Operations
335. Driver Behavior at Railroad Grade Crossings: Before and After Safety Campaign

1991

336. Thermogravimetric Analysis of Carbonate Aggregate to Predict Concrete Durability
337. Investigation of Rapid Thermal Analysis Procedures for Prediction of the Service Life of PCCP Carbonate Coarse Aggregate
338. The Value of the County Engineer: Strategies for Expanding the Shrinking Employment Pool
339. Multi-Project Scheduling Procedure for Transportation Projects
339A. (A Micro-Computer Based Linear Scheduling Applications for Highway Construction Project Control) (1994)
340. Development of an Integrated Data Base for Bridge Maintenance
341. Bond Enhancement Techniques for PCC Whitetopping
342. Use of GPS for Photogrammetry

343. Non-Corrosive Tie Reinforcing and Dowel Bars for Highway Pavement Slabs
344. Scour Susceptibility at Bridges in the State of Iowa
345. Electronic Bulletin Board System
346. Image Analysis for the Characterization of Materials for Highway Construction

1992

347. Impacts on Safety of Left Turn Treatment at High Speed Signalized Intersections
348. Recruiting and Retaining Women/Minorities for Public Sector Engineering Positions
349. Recycled Paper Erosion Control Mats
350. Channel and Flood Plain Aggradation in the Iowa River Basin
351. Bentonite Treatment for Economical Dust Reduction on Limestone Surfaced Secondary Roads
352. Stream Stabilization in Western Iowa
353. Epoxy-Coated Strands in Composite Precast Prestressed Concrete Panels
354. An Engineering Study to Design Triple Box Culvert Standards
355. The Role of Magnesium in Concrete Deterioration
356. Economical Production of Calcium Magnesium Acetate
357. An Expert System for Forecasting Fog on US 30 in Cedar Rapids

1993

358. Evaluation of Microcracking and Chemical Deterioration in Concrete Pavements
359. Airborne GPS
360. Field Evaluation of Engineering Fabrics for Asphalt Concrete Resurfacing—Audubon County
361. Development of a Model for the Ice Scraping Process
362. Design Methodology for Corrugated Metal Pipe Tiedowns: Phase II
363. Clarifying the Quadrennial Needs Study Process
364. Automated Recording of Bridge Inspection Data in the PONTIS Format
365. Evaluation of Bridge Replacement Alternatives for the County Bridge System
366. Field Data Acquisition Technologies for Iowa Transportation Agencies
367. Solar Powered Highway Delineator System

1994

368. Construction Automation Using Pen-Based Computers
369. Bond Development in Concrete Overlays
370. Pipe Rehabilitation With Polyethylene Pipe Liners
371. Development of a County Condemnation Policy and Procedure Manual
372. Full Scale Field Measurements of Ice Scraping Loads
373. Investigation of Plastic Pipe for Highway Applications

373A. Investigation of Plastic Pipe for Highway Applications—Phase II

374. Field Measurements of Ice Scraping Loads on Front Mounted Plow Blades
375. Transportation Research Board Education for County Engineers
376. Metric Training for the Iowa Highway Industry
377. Field Data Collection & Reporting for Construction
378. Metric Short Course for the Office of Bridges and Structures
379. Recycled Asphalt Shingles for Slurry Leveling and Crack Filling
380. Maturity and Pulse Velocity Measurements for PCC Traffic Opening Decisions
381. Development of Benchmark Data for the Iowa DOT Construction Office
382. Investigation of Two Bridge Alternatives for Low Volume Roads

1995

383. Iowa Streamflow-Gaging Network Analysis
384. Expansive Mineral Growth and Concrete Deterioration
385. Stream Stabilization in Western Iowa: Structure Evaluation and Design Manual
386. Distributing State Road Use Tax Funds to Counties
387. Soft Photogrammetry for Highway Engineering
388. Road Network Mode Spreadsheet for Service Level Decision Making
389. Development of a City Condemnation Policy and Procedure Manual
390. Testing of Old Reinforced Concrete Bridges

1996

391. Optimal Usage of De-Icing Chemicals when Scraping Ice
392. Review of Cold In-Place Recycled Asphalt Projects
393. Preventing Cracking at Diaphragm/Plate Girder Connections in Steel Bridges
394. Transportation Program Management System
395. Statistical Summary of Selected Iowa Streamflow Data
396. Image Analysis for Evaluating Air Void Parameters of Concrete
397. Field Laboratory Testing of Damaged Prestressed Concrete (P/C) Girder Bridges
398. Hydraulics of Slope-Tapered Concrete Pipe Culverts
399. Field Testing of Integral Abutments
400. Determining the Optimal Usage of Chemicals in Winter Highway Maintenance
401. Embankment Quality
402. Access Management Awareness Program
403. A Comprehensive Quality Incentive Program for Portland Cement Concrete Paving
404. Maximizing the Use of Roadway Weather Information Systems
405. Impact of Deck Cracking on Durability

1997

406. Determine Initial Cause for Current Premature PCC Pavement Deterioration
407. Hydro-surface Preparation and Coating for Painted Structural Steel
408. Glass Fiber Composite Dowel Bars for Highway Pavement
409. Evaluation of Photoacoustic Spectroscopy for Quality Control of Cement
410. Investigation of Two Bridge Alternatives for Low Volume Roads—Phase II
411. An Improved Computer Program for River Valley Rating Curves
412 Development of a Computer Controlled Underbody Plow
413. Recycled Shingles for Granular Surfaced Roadway Dust Control
414. Superpave Mix Designs for Low Volume Roads
415. Aggregate-Related Factors of Critical VMA in Asphalt Paving
416. Development of Materials Training Course for Technicians
417. ICEA Service Bureau

1998	418.	Feasibility of Automated Distress Data in the Quadrennial Needs Study
	419.	Education on Urban Corridor Issues through Computer Animation
	420.	Field Evaluation of Alternative Load Transfer Device Locations in Low Traffic Volume Pavements
	421.	Use of Railroad Flat Cars for Low Volume Road Bridges
	422.	Pretreatment for Reduction of Asphalt Absorption in Porous Aggregate
	423.	A Commemorative History of the IHRB
	424.	Steel Diaphragms in Prestressed Concrete Girder Bridges
	425.	Field Demonstration Project: Reclaimed Fly Ashes as Select Fill Under PCC Pavements
	426.	Mobility and Safety Impacts of Winter Storm Events in a Freeway Environment
	427.	Evaluation of High-Slump Concrete for Bridge Deck Overlays
	428.	Effective Structural Concrete Repair
	429.	Evaluation of Appropriate Maintenance Repair and Rehabilitation Methods for Iowa Bridges
	430.	Regional Approaches to Landslide Interpretation and Repair
1999 (through July)	431.	Reduction of Concrete Deterioration by Ettringite Using Crystal Growth Inhibition Techniques
	432.	Ultrathin Portland Cement Concrete Overlay Extended Evaluation
	433.	Highway Needs Methodology, Analysis and Evaluation
	434.	Use of Abrasives in Winter Maintenance
	435.	Thin Maintenance Surfaces—Phase II (with Guidelines)
	436.	Retrofit Methods for Distortion Cracking Problems in Plate Girder Bridges
	437.	Performance of Strip Seals in Iowa Bridges, Pilot Study
	438.	Integral Abutment Bridge with Precast Concrete Piles
	439.	Light Prestressed Segmented Arch (LPSA) Bridge Technology

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