RESEARCH
AND DEVELOPMENT

"Implementing research findings"

IN COOPERATION WITH THE

Local Road Research Board

"Sponsoring research for county and municipal roads and streets"

RESEARCH REVIEW
VOLUME I
The Implementation Status Of
Local Road Research Board Projects
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The Implementation Status Of
Local Road Research Board Projects

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Investigation No. 645

Prepared for the
LOCAL ROAD RESEARCH BOARD
MINNESOTA DEPARTMENT OF TRANSPORTATION
ST. PAUL, MINNESOTA  55155

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The Minnesota Local Road Research Board was formed by the Legislature in 1959. The function and purpose of the Board is described by the motto, "Sponsoring Research for County and Municipal Roads and Streets".

The Board includes four county engineers, two city engineers, three representatives of the Department of Transportation and a representative of the University of Minnesota, Department of Civil Engineering. Their basic responsibility is to select and fund research projects that are of interest to the cities and counties. The funding for the projects sponsored by the Board has been set at up to one quarter of one percent of the municipal state aid and county state aid funds. These funds are credited to a special account and are administered through the Research and Development office of the Minnesota Department of Transportation.
INTRODUCTION

This report is the first of several volumes prepared for the Minnesota Local Road Research Board (LRRB) which contain summaries of highway research projects which have been conducted in Minnesota. These summaries will be valuable references to City and County Engineers and others who are responsible for the construction and management of roads, streets, highways and other related facilities.

Volume I summarizes over 50 research projects which have been sponsored wholly or in part by the Minnesota LRRB since 1959. These projects cover a wide variety of subjects including geometric standards, pavement design and evaluation, materials evaluation, and roadside turf establishment to name a few. Much of the information resulting from these projects is of value to all city and county engineers, as well as Mn/DOT engineers and the industry.

To make this information more accessible, a review of each of the projects has been made including a statement for each on how it has been implemented. Recommendations are included regarding further implementation. The projects are to be reviewed periodically to update the implementation status. The updated pages will be distributed to supplement this report.

The research projects sponsored by the Minnesota LRRB are divided into major subject areas. A brief description of the work accomplished and how the work has been implemented is included.

This report is intended to be used as a quick reference to determine what information is available from the Mn/LRRB projects. The summaries will provide a review of the research sponsored by the Minnesota LRRB and an indication of the benefits that have been and can be derived from this work.

Where a subject is determined to be of significant interest to city and county engineers, a RESEARCH IMPLEMENTATION SERIES pamphlet will be produced. Such subjects as special asphalt mixtures and application of recycling techniques will be covered.
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BRIDGES

Investigation No. 639- "Bridge Deck Deterioration and Restoration"

Description: Four reports, final report written, waiting approval. The effectiveness of various materials and systems for reducing corrosion of reinforcing steel in bridge decks and ultimately spalling of the surface concrete are being evaluated. Included are liquid and preformed membranes with bituminous overlays, modified concrete and epoxy coated rebars.

Implementation: Many items from this project have been implemented. Investigation No. 639 first identified the cause of the bridge deck deterioration problem as being corrosion of the reinforcing steel of the bridge decks induced primarily by salt and moisture. Secondly, it identified a number of systems that can be employed to protect the rebars from corrosion and evaluated these systems for potential use. A bridge deck prioritization rating system was developed from this investigation and is presently used by the D.O.T. This project has been closed and a final report is pending approval by FHWA. Continued evaluations of protection systems are being continued under special study 367. A number of changes in design of a bridge deck and construction has been made as a result of this investigation.

Investigation No. 640- "Bridge Deck Anti-Frost Treatments"

Description: No report found. The purposes of the study were to document the nature and extent of the problem of frost on bridge decks and to evaluate the use of various materials for counteracting the problem. It was found that the occurrence of bridge deck frost was difficult to predict. No material is found to adequately prevent the frost from forming.
Implementation: There were no apparent results from the study that could be implemented. One important item, however, is the formation of frost on an exposed object or body such as a bridge deck is dependent on a combination of surface temperature and the dew point. Whenever the temperature of the bridge deck drops below the dew point and also below 32 degrees, the available moisture in the air will condense on the bridge deck and form frost. The natural ground provides some degree of heat to pavements, whereas free standing objects such as a bridge deck radiate heat, particularly on clear cold nights with little or no wind movement. They have no energy input to them such as pavements would from the natural ground. This condition results in a loss of temperature oftentimes to the point where it decreases below the air temperature. This radiant cooling effect under proper conditions can occur and cause frost even at temperatures well below zero.

Investigation No. 648 - "Design of Bridges in Areas of Unstable Soils"

Description: 1979 Report. A state-of-the-art study is being conducted in an attempt to define designs which will reduce soil mass movements for bridges that are constructed in unstable soil areas.

Implementation: This study makes information available regarding the cause and effect of the slope stability problems, particularly the Red River Valley clay soils area. It has identified procedures used that are shown to be effective in reducing slope stability problems. Six to one or greater fill slopes and placement of support piles into stable strata are two items which are effective.
ICE REMOVAL AND SALT

Investigation No. 604- "Ice Removal on Highways and Bulk Storage of Chloride Salts"

Description: 1962 Report. The comparative effectiveness of several chlorides, salts and abrasive-chloride salt mixtures for ice removal was determined in a field trial. The storage characteristics (moisture, crusting and caking) of these materials were monitored. Based on ice removal action, economy, and storage characteristics, a mixture of two thirds sodium chloride and one third calcium chloride was the best mixture.

Implementation: This report recommended application rates and combinations of materials for application and for effective outdoor storage of the materials. Conditions and technology has changed considerably since the 1962 report and many studies have since been conducted. Investigation No. 645 is beginning to look into various aspects of ice and snow removal and could possibly compile the information currently available regarding this subject.

Investigation No. 620- "Effectiveness of Anti-Corrosion Additives in Deicing Salts"

Description: 1967 Report. A laboratory study was conducted to evaluate the effectiveness of several chemical inhibitors in reducing corrosion of auto body steel by deicing salts. Laboratory results showed significantly lower corrosion rates when the inhibitors were used. However, in field tests, where natural atmospheric corrosion was involved, no difference between treated and nontreated salts was noted.

Implementation: Anti-corrosion additives generally are not used by cities, counties or state to date. A brief review may be in order to determine if any advances have been made in anti-corrosion additives since the 1967 report.
LITERATURE AND RESEARCH REVIEWS

Investigation No. 618- "Reviewing and Abstracting Technical Reports"

Description: Technical reports and magazine articles of interest to state and local transportation engineers are abstracted. About twelve abstracts are published and distributed monthly.

Implementation: This is a continuing project producing monthly abstracts and the implementation should be, with the concensus of the Local Road Research Board, to continue.

Investigation No. 645- "Implementation of Research Findings"

Description: No Report. Selected research reports by various agencies (including Mn/DOT) are digested and assistance given to county and municipal engineering personnel in implementing appropriate finding. Methods include slide presentations, summary reports and field demonstrations.

Implementation: This project, as the title infers, is an implementation facilitation project. A committee is formed by a Local Road Research Board which selects topics to be implemented or expanded upon and directs the contract agency to perform the necessary tasks. To date, special presentations and information packages have been prepared in the following areas:

- Pavement Evaluation - information presentations and documentation
- Recycling - slide-tape
- Effects of Heavy Loads - slide-tape
- Pavement Surface Condition Survey - slide-tape
- Fabric Technology - technical classes
- Water Quality - memos, sprinkle treatments - memo

Further information regarding the availability of these packages can be obtained from the Minnesota Department of Transportation, Office of Research and Development.
LOAD CAPACITY

Investigation No. 603- "Load Carrying Capacity of Flexible Pavements"

Description: 1968 Summary Report. The Benkelmen Beam was evaluated as a tool for determining roadway strength. The correlation between Benkelmen Beam and plate bearing values was not good. However, adequate relationships were developed between Benkelmen Beam deflection, pavement structure and pavement performance. Procedures were developed for setting spring load restrictions using Benkelmen Beam data.

Implementation: The procedures developed in this investigation have been implemented by Mn/DOT and various counties that conduct Benkelmen Beam deflection testing. A problem with the use of the system occurs when pavements are reevaluated after an overlay is placed. Often, the resulting tonnage after the overlay is the same or less than before. The reason for this comes from the reduction in the allowable deflection due to the increase in the thickness of the mat. An updated or new procedure should be developed.

Investigation No. 630- "Field Study on the Effect of Overlays on Flexible Pavement Deflections"

Description: 1968 Report. Benkelmen Beam deflection tests were run on 25 bituminous roadway locations throughout the state before and after they were overlaid. From the results, prediction models were developed for estimating the strengthening effect of various thickness of bituminous overlays.
Implementation: The results of the investigation yielded a general 11 percent reduction in deflection per inch of bituminous overlay for pavements on plastic soils. The implementation of this investigation would be and has been the use of the 11 percent reduction in overlay design practices. Further research would be necessary to extract all the information that is available from the current generation of nondestructive testing equipment.

(Note: MPM has had the opportunity to measure deflections before and after overlays on several sections and definite reduction in deflections and improvement in deflection basin characteristics have been observed in all cases).
MISCELLANEOUS

Investigation No. 638- "Evaluation of Solid Waste Material for Highway Uses"

Description: 1975 Report. A state of the art report was prepared on the highway oriented uses of three solid waste materials in large supply in Minnesota, taconite tailings, fly ash and boiler slag.

Implementation: Specifications and/or standards were prepared and are available to encourage the usage of these three materials. The implementation could be considered a success in some cases since these three waste materials have achieved some degree of market value. Taconite tailings and boiler slag have been used as mineral aggregates for bituminous pavement surfaces and for fill applications. Fly ash has been used as an additive to portland cement concrete and also at times as fill for embankment construction.

Investigation No. 644- "Compactor Vehicle Weight Limitations"

Description: 1975 Report. The study was conducted to determine the impact of permitting refuse compactor vehicles to load to a rear axle load of 11 tons.

Implementation: This report provides information regarding the nature of axle loadings on various styles and models of garbage trucks and also on the impact that these vehicles could have on various pavement sections. The implementation of this project should evolve around the usage of this information for developing permit standards for garbage truck operation and also for information for both pavement design and for vehicle chassis design.

Investigation No. 647- "Aesthetic Coatings for Boulevards and Medians"

Description: 1978 Report. A state of the art study was conducted to identify the types of materials for coating boulevards and medians where grass may not survive.
Implementation: The implementation of this study is limited to referring to the report to provide information to those interested regarding the various materials available for providing aesthetic coatings alongside pavement surfaces.

Investigation No. 652- "Aggregate Inventory Study"

Description: 1982 Report. The study was undertaken to determine the type and extent of the aggregate supply problem in Minnesota and method to locate, preserve and conserve aggregate supplies. Phase I will be a pilot study of a selected area to determine the type and extent of the aggregate supply problem. Phase II will be a state-of-the-art study of the methods local and state jurisdictions have used to find, preserve and conserve aggregate supplies.

Implementation: Phase I is being completed and it has not been available for review.

Investigation No. 657- "Evaluation of Automatic Vehicle Classification Devices"

Description: No report. Three types of vehicle counter/classifiers (Streeter-Amet, Safetran and Stevens) have been field tested against a manual traffic count in order to determine the accuracy of the classifiers.

Implementation: The study has been completed to date but early indications are that there are no devices that provide all of the information that would be required to be a successful counter/classifier.
Investigation No. 612- "Experimental Base Stabilization Project"

Description: 1969 Report. A number of test sections were constructed in Wadena County to evaluate the effectiveness of stabilizing the upper portion of a sand subgrade soil with several types of bituminous materials. Stabilizing to a depth of 4 in. with asphalt emulsion or cutback asphalt and applying a sand seal coat resulted in a very satisfactory structure.

Implementation: Bituminous stabilization of granular subgrades is used in a variety of ways by agencies throughout the country. Although this project was a success and resulted in an effective and perhaps cost effective way of producing a bituminous surface, no implementation procedure was adopted. Various versions of this type of construction are being or have been used by various agencies such as the City of Anoka and to a different extent, the U.S. Forest Service. This project has significant merit and would be a candidate for implementation consideration, particularly by those counties or cities that have sandy soils. Sensitivity to weather and availability of experienced personnel are major factors for this form of construction. The City of Anoka discontinued their work because their blade operator retired. See RESEARCH IMPLEMENTATION SERIES, NO. 1, "Bituminous Pavements Using Sand Aggregates", for further information.

Investigation No. 629- "Evaluation of Bituminous Surfaces with Finer Aggregates"

Description: 1971 Report. Bituminous mixtures utilizing aggregates with a finer gradation than permitted by current specifications were used as wearing courses on several low volume roads in three counties, Pine, Koochiching and Waseca. After five years of observation, it appears the use of these aggregates will result in satisfactory bituminous wearing courses on low volume roads.
Implementation: Mn/DOT Spec. 2335 was based, in part, on this project. The project results were positive and encouraging. The results may be more meaningful today than before as sources for bituminous aggregates become scarce. The finer aggregates that were used in the study were in fact basically subgrade soils that were available in the project areas. For implementation of this project, the bituminous office presently has a specification for a 2331 modified and a 2341 modified mix. It essentially is a specification which allowed the manufacture of a fine mix without having to use the traditional 2361 mix gradations. This specification was developed to provide an alternate surface mix design when thick overlays were not required. A 2335 specification is also available which can be used instead of 2331 to take advantage of local aggregate sources. Implementation can be accomplished by using Mn/DOT Specification 2335. See RESEARCH IMPLEMENTATION SERIES, NO. 1, "Bituminous Pavements Using Sand Aggregates", for a summary of the current specifications available.

Investigation No. 641- "Crack Reflectance of Bituminous Overlaid PCC Pavement"

Description: 1981 Report. Various procedures and materials are being evaluated for reducing the amount of crack reflectance on bituminous overlaid PCC pavement. The most promising solution appears to be breaking the old concrete prior to overlaying.

Implementation: Break and overlay is being used nationwide. Investigation 641 has been completed. The research of crack and overlay as recommended by this project is continuing under Investigation No. 208. The final implementation of the project depends on the outcome of Investigation 208. The other aspects of the project, such as the relationship between thickness of overlay and crack reflectance and the stress relief layer may provide useful information which could ultimately become part of a rehabilitation design procedure.
Investigation No. 642- "Evaluation of Bituminous Surfaces using the Turbulent Mass Process"

Description: 1976 Report. The use of the turbulent mass process was observed and evaluated on a number of bituminous projects. Test results indicate that the quality of the mix produced by this method is comparable to that produced by the traditional pugmill.

Implementation: Fully implemented. The use of the turbulent mass process has probably been fully implemented by the industry. Investigation 642 was different in the respect that the process was developed and was being implemented prior to the investigation. The investigation was conducted to determine the suitability of asphalt mixes produced by the turbulent mass process.

Investigation No. 646- "Evaluation of Recycling Bituminous Pavements"

Description: 1978 Report. A field project was constructed to evaluate the feasibility of recycling bituminous pavement and aggregate base into a new bituminous pavement. The quality of the pavement appears to be comparable in quality with a control section constructed from virgin aggregate.

Implementation: Implementation rapidly occurring worldwide. This project is in the process of being implemented. A Mn/DOT specification exists for recycled asphalt mixes. The asphalt producers are in the process of modifying their plants or have modified their plants to produce recycled asphalt mix. This is probably one of the most well known Local Road Research Board projects since it resulted in what is nationally known as the Minnesota Heat Transfer Method of Hot Mix Recycling. To further the implementation of hot mix recycling among the cities and counties, a slide-tape presentation has been prepared which describes hot mix recycling and how local agencies can make use of this process.
Investigation No. 650—"Pilot Program for Evaluation of the Structural Adequacy of Flexible Pavements for Counties and Municipalities"

Description: 1980 Report. Methodology is being developed for use in evaluating flexible pavements so that more realistic load restrictions can be set and improvements can be properly designed and programmed on a priority basis. Data were collected in three Minnesota counties.

Implementation: Portions of the "pilot project" being implemented by some cities and counties. This project was developed in an attempt to implement several other research projects on a city-county basis. The projects which were to be implemented established methods of evaluating pavement surface condition, Investigation No. 189, and pavement strength, Investigation No. 603. To date, there has been no known implementation of Investigation No. 650 by other counties or cities. Several of the counties originally involved have continued on with portions of the pilot program. The cumulative distribution method of evaluating spring load capacity as recommended in the report has been adopted by Mn/DOT. Condition rating and strength measurement services are now available to cities and counties from several private consulting firms around the country.

Investigation No. 654—"Use of Sulphur in Construction and Maintenance of Pavements"

Description: In Progress. This study is a laboratory and field study to evaluate the use of sulphur and sulphur asphalt mixtures in pavement construction and maintenance.

Implementation: Implementation based on cost of asphalt and sulfur. The use of sulphur asphalt mixtures is presently under investigation. A specification has been produced by the bituminous office although not published. Implementation of the use of sulphur in asphalt mixes will depend finally upon the performance of mixtures, economics, and the ability to adapt existing asphalt plants so that they can utilize sulphur.
Investigation No. 655- "A Synthesis of Surfacing Design and Construction Technology for Low Volume Roads"

Description: 1982 Report. Under this study, present surfacing design and construction methods for low volume roads are identified and rated for applicability in Minnesota.

Implementation: This investigation was a synthesis of low volume road technology. The implementation would be the implementation of any recommendations that come from the report such as the development of low volume design procedures and broadening of the use of local aggregates and/or the setting up of a research project to study the design requirements for low volume roads.

Investigation No. 656- "Use of Oversized Aggregates in Plant Mixed Bituminous Pavements"

Description: In Progress. The feasibility of constructing the base course of hot plant mixed bituminous pavement using oversized aggregates, including crushed, salvaged concrete, is being evaluated. If successful, this would reduce asphalt demand.

Implementation: Implemented by several Minnesota agencies. The project is in the beginning phases and any implementation that could result would depend on the outcome of this investigation. The use of oversized aggregates requires the placement of thick lifts and is therefore limited to pavements that require thick asphalt layers.
QUALITY CONTROL AND LABORATORY TESTS

Investigation No. 613- "Field Trial of a Speedy Moisture Meter"

Description: 1963 Report. Moisture meters were used on a number of grading projects which included a wide range of soil types. Some base and sub-base materials were also tested. The device proved to be much faster than, and results were in good agreement with, conventional field test methods.

Implementation: Widely implemented. The speedy moisture meter and larger version specifically designed for aggregate base materials are widely used for moisture control on grading and paving projects at this time. They have been so successful in fact that nuclear meters have yet to make significant headway in this area.

Investigation No. 622- "Evaluation of Nuclear Moisture and Density Gages"

Description: 1966 Report. The accuracy of several nuclear instruments to determine moisture and density of soils and base aggregates and the density of bituminous pavement courses were evaluated in the laboratory and in the field. Results generally agree quite well with results of test runs by standard methods.

Implementation: Nuclear meters are currently used quite widely for density measurements, particularly on aggregate base and paving operations. They have not been used very much for density and moisture control in grading operations. Nuclear meters have advanced significantly since the date of this report and a brief state-of-the-art summary may be in order.
Investigation No. 625- "Evaluation of Automatic Conveyor Weighing Systems"

Description: This study evaluated the acceptability of an automatic conveyor weighing system as a means for determining pay quantities for certain highway construction materials. While the device was sufficiently accurate, it was difficult to maintain the required calibration under working conditions.

Implementation: Automatic conveyor weighing systems are commonly used at this time and have been used for pay quantities provided proper calibration and consistency can be demonstrated on a case by case basis (Henry Mehmen, Grading and Base Construction Engineer suggested that a review of the current state-of-the-art regarding automatic conveyor weighing systems would be appropriate at this time).
SPECIFICATIONS AND STANDARDS

Investigation No. 637- "Development of a Uniform Set of Standard Specifications for Underground Utilities"

Description: 1974 Report. Input from various governmental agencies, associations and utility industries were requested, digested and synthesized into a two volume set of specifications, one for water and one for sewer.

Implementation: The reports were accepted and published by the League of Minnesota Municipalities and distributed to all of its member agencies. The first publication was in 1975. Since that time, a committee had been reviewing and accepting changes for the publication which was re-published in 1979 containing the recommended changes to that date. The specification is used by most municipalities at least within the metropolitan region. A committee is currently active in reviewing the specifications and recommended changes to the specifications to assure that a modern up-to-date set of specifications would continue to exist.

Investigation No. 651- "Width Standards for State Aid Streets and Highways"

Description: 1979 Report. The purpose of the study is to review and document the background and rationale of present state aid street and highway standards. The information will be of value to engineers for supporting appropriate standards against local pressures to compromise them.

Implementation: A slide-tape show will be developed and made available to assist engineers, designers and planners in showing council members and the public why standards exist and also why they are needed.
SUBGRADE AND BASE MATERIALS

Investigation No. 601- "Laboratory Evaluation of Soil Lime Mixtures"

Description: 1962 and 1964 Reports. Laboratory tests were conducted to determine the effect of hydrated lime on the physical and strength properties of five typical Minnesota fine grain soils and two substandard base aggregates.

Implementation: Has potential for use as a method of improving the strength of some clay soils. The reports contain no specific recommendations. They do however, describe the results of a large amount of traditional laboratory work. The Hveem Stabilometer R-value test was rejected for use with lime stabilized soil mixtures because the values were too high. The results are available for review but no indication of implementation was found. (Reviewers note: It is expected that the Resilient Modulus of lime stabilized soils could be used to characterize strength. The R-value test depends on extruding moisture from the material while under high pressures. There are several projects on the Trunk Highway system such as T.H. 15 north of Fairmont that have lime mixed in the embankment. These could be tested for strength using deflection testing and elastic layer analysis.

Investigation No. 607- "Nobles County Base Stabilization Project"

Description: 1967 Report. Test sections were constructed to investigate the feasibility of stabilizing a local aggregate with cutback asphalt, sodium chloride and calcium chloride. The chlorides migrated out of the granular layer. None of the additives provided any definite benefits in expediting construction or improving performance.
Implementation: The implementation of this project, if any, would consist of the distribution of information regarding the results which would describe the lack of success when using chloride salts. Further evaluation of the cutback asphalt stabilizations of raw aggregates however at this time, may be warranted with attention given to cost. See RESEARCH IMPLEMENTATION SERIES, NO. 1, "Bituminous Pavements Using Sand Aggregates", regarding the use of local aggregates for hot-mixed asphalt surfacing.

Investigation No. 608- "Bituminous Stabilization"

Description: A laboratory procedure was developed for designing soil bituminous mixtures for use as a subbase or subgrade material. It included a sample conditioning period and testing with the Hveem Stabilometer and Cohesiometer.

Implementation: This project led to Investigation No. 612, a field test of a number of stabilized soil sections (stabilized local aggregates), which is discussed under the pavement field category. This research was the beginning of a process which now includes the use of local fine aggregates in hot-mixed asphalt surfacing as summarized in RESEARCH IMPLEMENTATION SERIES, NO. 1, "Bituminous Pavements Using Sand Aggregates".

Investigation No. 611- "Experimental Lime Stabilization Project"

Description: 1971 Report. Experimental sections were constructed on a county road in Norman County in which the upper portion of the clay subgrade soil was stabilized with lime. Based on cost and performance comparisons with adjacent untreated sections, the use of lime is not economical for similar climates and soils.
Implementation: The project resulted in a pavement section which was not economical and performed poorly. This was based on using the lime stabilized subgrade soils as a replacement for aggregate base. The results of this project and Investigation No. 601, described above, did however show that a general increase in material strength can be obtained by the addition of hydrated lime to the soils. This may be an area worthy of further investigation, not as a total replacement of aggregate base materials, but rather as a modification of the strength properties of the subgrade through the addition of small percentages of hydrated lime. This approach should involve the stabilization of several feet of subgrade soils with less than 3 percent lime. Actual trial mixes should be evaluated to determine the effect of the lime on the soil and the volume which would result in favorable strength characteristics.

Investigation No. 617- "Laboratory Study of Bituminous Stabilization of Silty Soils"

Description: 1963 Report. A laboratory procedure was developed for designing bituminous - silty soil mixtures. The stabilometer test gave the most reliable results. The CBR test had some merit. Road tar proved to be the most effective stabilizing agent for silty soils.

Implementation: This project led to Investigation No. 621 described below.
Investigation No. 621- "Experimental Field Project on Bituminous Stabilization of Silty Soils"

Description: 1965 and 1972 Reports. Test sections were constructed to evaluate the effectiveness of stabilizing the upper portion of a silty subgrade with two different recommended materials, road tar and cutback asphalt, thereby reducing the required thickness of granular base. The use of road tar proved to be effective, but was not economical compared to granular base. The relative field performance of the stabilized sections agreed with laboratory test results from Investigation No. 617.

Implementation: No implementation was recommended due to the cost of the stabilization of the silty soils as compared to the aggregate base costs. These recommendations were based on a 1972 cost analysis and it may be worthwhile to review the present costs.

Investigation No. 624- "Degradation of Crushed Rock and Gravel Base Materials"

Description: Report at printer. Samples of aggregate base were taken following various construction operations on several projects and also periodically after completion to determine the amount of degradation that occurs. Various laboratory tests were conducted in an attempt to find a test that would indicate a tendency for an aggregate to degrade.

Implementation: Some aggregates degrade when exposed to freeze-thaw and/or salt. No specific implementation recommendations were found. (The full effects of degradation have not been sufficiently defined to develop an implementation). Additional work in the area of degradation at this time are to evaluate the effects of freeze-thaw cycles, the degradation effects due to salt, and the possible effects of degradation on pavement performance.
SURFACE TREATMENTS AND CRACK SEALING

Investigation No. 626- "Criteria for Seal Coating Bituminous Surfaces"

Description: The purpose of the study was to develop criteria to determine the need for seal coating bituminous surface. Interviews with maintenance engineers indicated the degree of surface "dusting" was most used in determining seal coat needs. Following a series of field condition surveys "dusting rating" was selected as the most appropriate criteria.

Implementation: Implemented by various agencies nationwide. NCHRP project, 10-9, "Criteria for Need of Seal Coats on Bituminous Pavements" was conducted after this study which resulted in a booklet titled, "Surface Condition Rating System". This booklet describes a rating system which can be used to rate bituminous surfacing to evaluate the need for seal coating. This system has been implemented by various agencies throughout the United States. This system should be implemented either directly or by incorporation into a larger surface condition rating system by all agencies that have bituminous surfaced roads.

Investigation No. 643- "Need for Sealing Cracks in Bituminous Pavements"

Description: No report. Test sections have been established where no crack sealing work will be done on eight roadway segments. Their rate of deterioration is being compared to that of adjacent sections where normal crack sealing maintenance is being continued.

Implementation: This project has been terminated due to insufficient data for evaluation purposes. The subject has been continued in Investigation No. 660, which will again attempt to evaluate crack sealing.
TRENCH STUDIES

Investigation No. 610- "Backfilling Trench Excavations"

Description: 1971 Final Report. Utility trenches were dug, backfilled and monitored for settlement. Variables, including soil, type of compaction equipment and density. None of the procedures eliminated trench settlement completely.

Implementation: This project did not result in any specific implementation by itself, however, two investigations followed which resulted in a specific implementation of the relevant findings from this study. Compaction specifications are included in the specifications for the water, storm and sanitary sewers published by the Minnesota League of Municipalities.

Investigation No. 633- "Synthesis of Recent Trench Backfilling Studies"

Description: 1972 Report. Data obtained from Investigation No. 610 were re-analyzed and compaction procedures recommended for limiting settlement to given tolerable amounts for various soil types.

Implementation: This study lists compaction techniques and provides settlement prediction limits which can be designed for. A compaction specification has been included in the specifications for the installation of watermains and sanitary and storm sewers which has been published by the Minnesota League of Municipalities in 1975 and revised again in 1979.
VEGETATION AND EROSION CONTROL

(Reviewers Note: This subject area consists of twelve individual research investigations dealing with various aspects of plant growth along highways. The information that is available from these various investigations could form the basis of a very informative and useful leaflet or brochure which could present the highlights of the findings from each of these investigations.)

Investigation No. 614- "Vegetation and Erosion Control on Highway Slopes"

Description: This study evaluated various methods of controlling the flow of water, slope preparation and topsoiling, seeding and fertilizing. A number of commercial mulches and erosion control products, such as fiberglass, jute and paper fiber nettings and plastic resin spray materials were also evaluated.

Implementation: The findings of this research investigation were published in various magazines, scientific journals and also a portion of the material was included in one of the national Association of County Engineers manual series. The findings from this investigation were included in the appropriate sections of the Mn/DOT manuals and specifications.

Investigation No. 615- "Development of Ground Covers for Highway Slopes"

Description: 1970 Report. Over 500 accessions of plants with ground covering potential were evaluated at three university experimental stations and on selected roadside sites. Based on culture, hardiness, longevity, propagation, maintenance and general suitability, 34 varieties were recommended for use on highway slopes in Minnesota.

Implementation: This investigation lead to the development of Investigation 634, which included a more detailed roadside evaluation study.
Investigation No. 616- "Study of Grass Growth Retarders"

Description: The use of Malaic Hydrazide as a growth retardant for grass on Minnesota roadsides was investigated. While the retarding effects in some instances were good, they were inconsistent and dependent to a large extent on proper timing of application and quality of the turf. The cost of the material precludes its use indiscriminately.

Implementation: The use of grass growth retarders in Minnesota is now generally inconsistent with the philosophy of the management of roadside plant life. Some new growth retardants have been developed and show promise; however, their application would be contrary to the current range management approach to roadside vegetation. Information from this report was published in at least two scientific journals and requests for the report are still being received from locations throughout the world.

Investigation No. 619- "Methods and Materials for the Maintenance of Turf on Highway Right of Ways"

Description: Two reports and one bibliography. Various aspects of establishing and maintaining roadside vegetation were investigated. These included the selection of grass species, seeding and fertilization procedures, chemical growth regulation and mowing practices.

Implementation: This investigation was conducted by the University of Minnesota and contained a number of recommendations, many of which were implemented by either being inserted into maintenance manuals or other relevant manuals published by the D.O.T. This investigation lead, at least in part, to the development of the Design Review Team that was in existence for several years and now a function of construction review in the Engineering Standards Office. A portion of this study in selection of grass species lead to follow-up Investigation No. 635. Another result of the study was raising the mowing heights to approximately six inches which was found to produce better weed control, stronger turf grass and wildlife protection.
Investigation No. 635- "Evaluation of New Turf Grass Selections"

Description: The most promising turf grass clones studies under Investigation No. 619 were selected for further evaluation under several climatic and soil conditions. The best of these will be formally introduced for possible commercial seed production.

Implementation: This report is nearly completed. The FHWA has accepted the final report. This investigation may have suffered somewhat from lack of attention recently. A positive result of the investigation was that it got Northrop King interested in developing a low maintenance Bluegrass and they are carrying on with that process.

Investigation No. 628- "Plant Species Survival on Landscape of Planting Projects"

Description: One report. Factors which affect the survival of different plant species were analyzed. Survival was found to be dependent on a combination of factors, but the most important was the timing and adequacy of the amount of water applied during and following the planting operation.

Implementation: The findings were important and worthy of implementation. The results of this investigation were presented in several training sessions that were conducted around the state in the 1970's by Dr. Foot and his staff. The results now are, at least for Mn/DOT projects, an improved survival rate which is approximately 95 to 98 percent compared to 70 percent or less before this study was conducted. Maintenance men responsible for the actual mowing were informed of the importance of the plantings and attempts were made to reduce the number of plants mowed down during normal mowing operations. This information will be reinforced at future training sessions conducted by Dr. Foot and his staff. These sessions are advertised to city and county engineers and are open for city and county personnel to attend.
Investigation No. 632- "A Comparison of Selected Mulch and Soil Conditioners based on Survival and Growth of Woody Plants"

Description: No report. Several commercial mulch and soil conditioners were evaluated against the standard wood chip-fertilizer-peat moss combination. Due to the high mortality rate of the trees, Silver Maple and Green Ash, planted in this study, no conclusions could be reached.

Implementation: No implementation was possible due to the conditions described above. The results of this project, as in many research projects show that conditions originally not considered, can become the dominant controlling factors limiting the intended value of the research.

Investigation No. 636- "Effect of Deicing Salts on Woody Vegetation Along Minnesota Roads"

Description: Two reports. The study was conducted to determine how much of the so called "salt damage" to woody roadside vegetation in Minnesota is actually caused by deicing salt. Recommendations were made for reducing this damage. One method is selection of the appropriate species for each site.

Implementation: The Mn/DOT plant selection process is now based on the results of this investigation. A report may be submitted to the Transportation Research Board for presentation and publication.

Investigation No. 631- "The Removal of Competition as an Aid in Establishing Sumac on Highway Slopes"

Description: No report. Several methods of removing turf grass competition were used prior to direct seeding of Sumac. Only marginal success was obtained. The most promising system is a combination of tilling and chemical application.
Implementation: There was no report on this project. A write-up was developed in 1977, but not published. There has been no more work conducted. The basic results indicate that seeding of Sumac does not produce any results. Sumac seedlings were found to grow better amongst the Bluegrass but would not grow at all amongst Brome. Recent findings, probably not associated with this investigation, found that Sumac grows best if transplanted from an existing Sumac growth. Small plants grow from runners or rizomes. Small stock with approximately six inches of root on each side transplanted in a new site, will provide the best results.

Investigation No. 634- "Roadside Evaluation of New Ground Cover Materials"

Description: 1983 Report. The more superior woody ground cover materials from Investigation No. 615 was selected for further roadside evaluation under several climatic and soil conditions.

Implementation: The results of this project have received some interest. Additional copies of the report have been requested by some cities. The information is presented at training sessions conducted throughout the state by Dr. Foot and his staff, which city and county engineers or personnel can attend. The report contains a top ten list of species for each climatic or geographical region of the state and also for southwest facing slopes and northeast facing slopes.

Investigation No. 649- "Time Responses and the Susceptibility of Roadside Plants to Growth Regulations"

Description: Attempts are being made to relate time of day with the susceptibility of various plants to herbicide. This could result in smaller quantities of herbicide being used for vegetation control and also a selective control system, i.e., kill only selected species in a vegetated area.
Implementation: Limited information was found on this subject. Some reference was made by Dr. Foot to the use of herbicides on Canadian Thistles and the importance as to when a herbicide should be applied.

Investigation No. 653- "Growth Responses of Stunted Roadside Trees to Various Methods of Fertilization"

Description: No report. A number of stunted Green Ash trees will be fertilized by three commonly used methods (surface applications, liquid injection and tree spikes) to determine their relative effectiveness.

Implementation: The report for this investigation is almost finished. The information will be presented at the next round of meetings conducted throughout the state by Dr. Foot and his staff. Surface application of fertilizer showed the best results relative to cost.

Summary

The one common source of information for city and county personnel for all the above subjects appears to be through the meetings conducted throughout the state by Dr. Foot and his staff. The materials covered at these meetings vary from time to time, but the people presenting the information are familiar with all of the above investigations and can likely provide the information that is requested. A small leaflet or brochure describing the highlights of the above investigations and perhaps further advertisement of the sessions conducted by Dr. Foot would be the most effective implementation approach for this area.